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Marine Corps Research University

Enabling Logistics with Portable and Wireless Technology Study

AUTHORS

School of Industrial Engineering
  Dr. Soundar Kumara
  Dr. N. Gautam
Pennsylvania Transportation Institute
  Dr. Zolton Rado
  Dr. Robert Gray
School of Information Sciences & Technology
  Dr. Dave Hall
  Dr. Irene Petrick
Project Manager: Col. Barney Grimes, USMC (Ret)

MCRU PROGRAM MANAGER

Lt. Col. Ron R. Madrid, USMC (Ret), Penn State University

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1 Executive Summary

This report represents the final deliverable of the project titled *Enabling Logistics with Portable and Wireless Technology Study*.

The project charged the interdisciplinary team from Penn State University to investigate the *Applicability of Portable and Wireless Technology to USMC Logistics*. The interdisciplinary team is made up of participants from Department of Industrial Engineering, School of Information Sciences and Technology and the Pennsylvania Transportation Institute.

The objective of this study is to:

- Identify, describe and quantify how portable wireless technology can be most effectively used in the USMC Logistics Operational Architecture (OA).

This study is bounded and guided by the following considerations.

- Focus on Request Management (RM), Order Management (OM), Production Management (PM), Capacity Management (CM) and the Execution (E) of these four processes;
- Assume a single order manager function with multiple request managers;
- Evaluate the impact of portable/wireless technology on logistics processes using the performance metrics described within the OA logistics scorecard;
- Commercial-off-the-shelf (COTS) technology must interface with current and future systems architecture as described within the OA;
- Focus on critical, high priority weapons systems, services and supplies;
- Portable-wireless technology solutions will comply with or function outside the radio-frequency controls dictated by current military policy;
- Balance battlefield management and warfighter safety with wireless enabled logistics applications; and
- Recommend solutions that will be deployable with Marine Air Ground Task Forces and interface with Global Combat Support System – Marine Corps (GCSS-MC) as it is currently envisioned.

1.1 Study Description and Focus

This study employed a three-pronged approach to identify potential wireless applications that extend and improve U.S. Marine Corps logistics. The three parallel efforts included: (1) an assessment of the Marine Corps Logistics OA as it interfaces with the GCSS-MC; (2) a comprehensive study of private sector commercial wireless logistics applications, with an emphasis on inventory tracking and asset visibility; and (3) an assessment of current and emerging wireless technology solutions.

The challenge involved integrating these three efforts to identify the best features in the USMC logistics chain to be enabled with wireless technology. Our intent was to balance the potential for wireless applications with the unique USMC warfighting demands. The approach is shown in Figure 1.1.
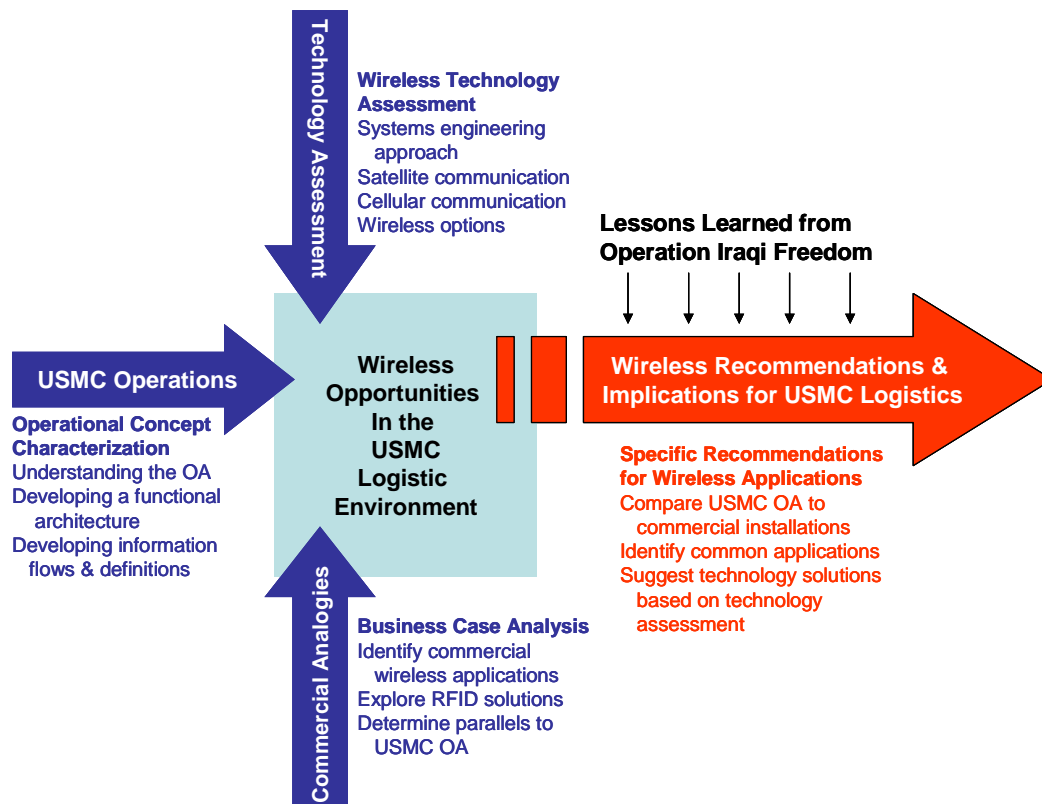
Figure 1.1: Three Penn State Parallel Efforts Combined to Support Recommendations of Wireless Applications in USMC Logistics

In recent years, significant advances have been made (and are continuing to be made) in the technology associated with wireless communications.   Advances in devices such as wireless sensors, portable computing devices, and local and wide band communications systems offer the USMC unprecedented opportunities to improve logistics activities in areas including:

- Automated detection and characterization of the state of USMC platforms and systems;

- Communication of system and human needs from the local point of service (POS) to regional and global arenas;
- Establishment of new supply chain information concepts and logistic situational awareness;
- Enhanced logistics and asset visibility based on improved (more precise) knowledge of what supplies and parts are needed and when they will be needed; and
- Transformation of current logistics planning to an accurate, predictive "preparation of the logistics battle space" concept analogous to current intelligent preparation of the battlefield planning.

To date, interoperability of these systems remains a major hurdle to implementation. Though standards are emerging or in planning, software and hardware are being developed on parallel tracks, and care is needed to integrate diverse system solutions. The study team's parallel efforts integrated three key perspectives. Figure 1.2 shows these:

- o Elements of the Physical World (e.g. commercial logistics)
- o Elements of the Communication Infrastructure (e.g. networks, communication devices)
- o Elements of the Information Infrastructure (e.g. data items and information)
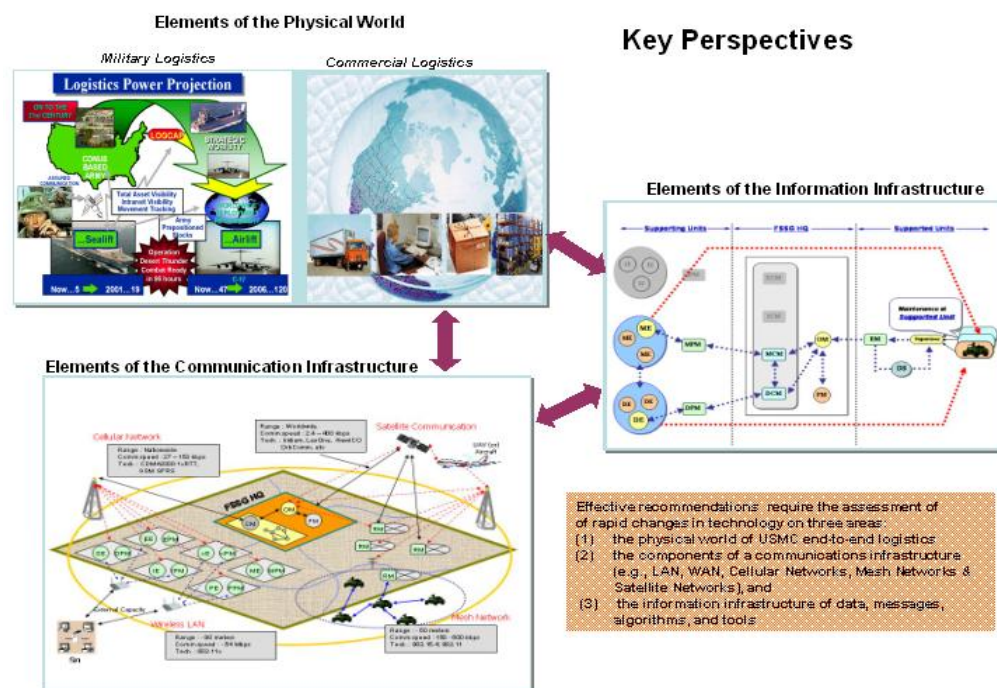
Figure 1.2: Three Key Perspectives

The Physical world in this study is dictated by the military and commercial logistics. This is necessary to generate an integrated perspective so that the best practices from the commercial sector can be used for implementation in the

Marine Corps. Such an implementation however, will be driven by the OA, which forms the foundation for USMC integrated logistics. These in turn, affect the overall communication infrastructure. Each of these perspectives in turn influences the other and hence an iterative methodology is used to determine the wireless solutions for USMC logistics.

1.2 Summary of Work Performed

The report represents the work performed by the team to address the tasks it was charged with.

Task 1: Review OA processes and performance measures

1.1 The sponsor shall provide reference materials and training on the OA to Penn State personnel. The materials and training will facilitate an understanding of the OA that will permit insight into those areas suitable for portable/wireless technology implementation.

1.2 The sponsor shall assist Penn State in compiling/reviewing any previous studies or other on-going DoD portable/wireless technology initiatives.

Task 2: Market research

2.1. A market survey will be conducted of (current) commercial off-the-shelf (COTS) and (future) developmental portable/wireless technologies that are/could be available to support the OA.

2.2. Based on an understanding of the OA and input from the Sponsor, identify those OA processes, which will benefit from COTS/developmental portable/wireless technologies. The identification of OA processes will be based on metrics to be mutually agreed upon between Penn State and the Sponsor. This task will assist in limiting/defining the scope of the study.

Task 3: Identify key data elements and information

3.1 For each process identified in Task 2, identify the key information required for both the execution and performance measurement of the process to no lower than SCOR Model Level 4 logistics support.

Task 4: Determine unique military considerations

4.1 Identify the unique military considerations that will inhibit or enhance the use of portable/wireless technology (e.g. deployability, environment, integration with current/future Marine Corps' IT systems). These considerations will include the availability of domestic and international bandwidth.

Task 5: Determine feasible solutions

5.1 Given the results of Tasks 2-4, recommend feasible portable/wireless solutions and architecture for those processes mutually agreed to between Penn State and the Sponsor. Solutions are further limited to no lower than SCOR Model Level 4 detail.

Task 6: Determine impacts of implementation

6.1: Determine the impact of portable/wireless technology implementation on the attributes defined within the OA (reliability, expenses, responsiveness etc.) as they apply to the selected processes. Where mutually agreed to between Penn State and the Sponsor, provide recommended future development insertion where appropriate.

1.3 Operational Concept and Vision

The OA developed by the USMC for use in deployed and garrison operations, formed the foundation of this study. The application of wireless technologies and devices to different OA processes was analyzed with deployed operations for perspective. The different aspects of the environment and operations that are unique to military operations were considered during the analysis. Substantial research efforts were expended to stay true to OA concepts.

The OA considers the following elements within the Combat Service Support (CSS): Supply, Maintenance, Transportation, General Engineering, Health Services and other Services. The logistics functionalities within the OA that are significant to CSS are Request Management (RM), Order Management (OM), Capacity Management (CM), Production Management (PM) and Execution (E). A critical review of the OA was performed and the specific nodes within were mapped to USMC organizations. In order to capture the real context of operations several interviews were conducted with USMC personnel. The inputs received were translated into an operational concept as shown in Figure1.3. Using this operational concept, communication requirements from node-to-node were identified. A detailed information flow analysis was done for all the seventeen use cases identified within OA. Each hop within the communication structure was analyzed for the associated attributes. This helped in computing the message size for a given request. We have computed the average number of

hops between any two nodes in the OA. This in turn defined the frequencies and hence helped in computing bandwidth requirements.
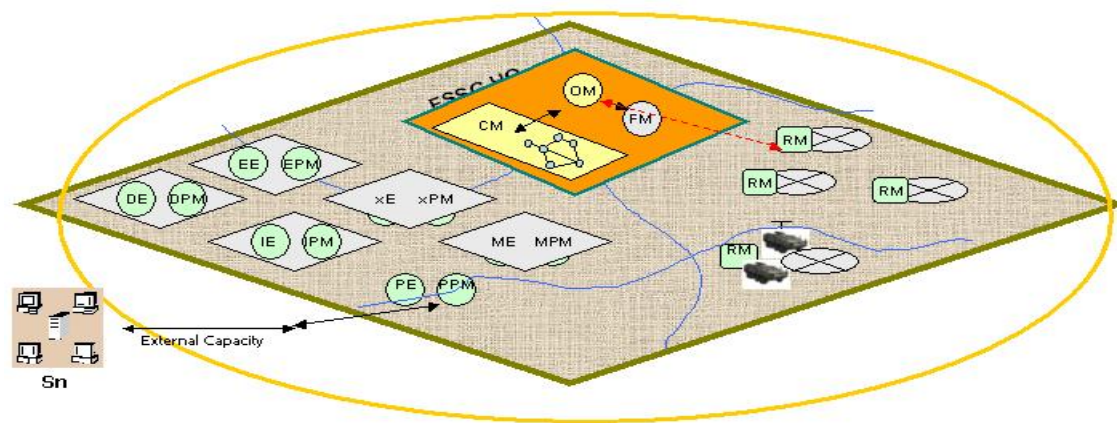
Figure 1.3: Operational Scenario

Identification of the requirements specifications for communication between the nodes was accompanied by a review of the commercially available devices, technologies that's could be applied to specific processes within the OA. Figure 1.4 shows the role of different wireless technologies within the global operational concept view of future USMC logistics support. The figure is representative of a Marine Expeditionary Force (MEF) that can execute concurrent sea based operations and sustained operations ashore. The supporting element (primary point of contact for all supported units) is assumed to be the Force Service Support Group (FSSG). The organizational mapping has been made to illustrate the use of the different wireless technologies and in future can be changed as designated by the domain experts within USMC.

1.4 Notional Description of the Futuristic Wireless Enabled OA Processes
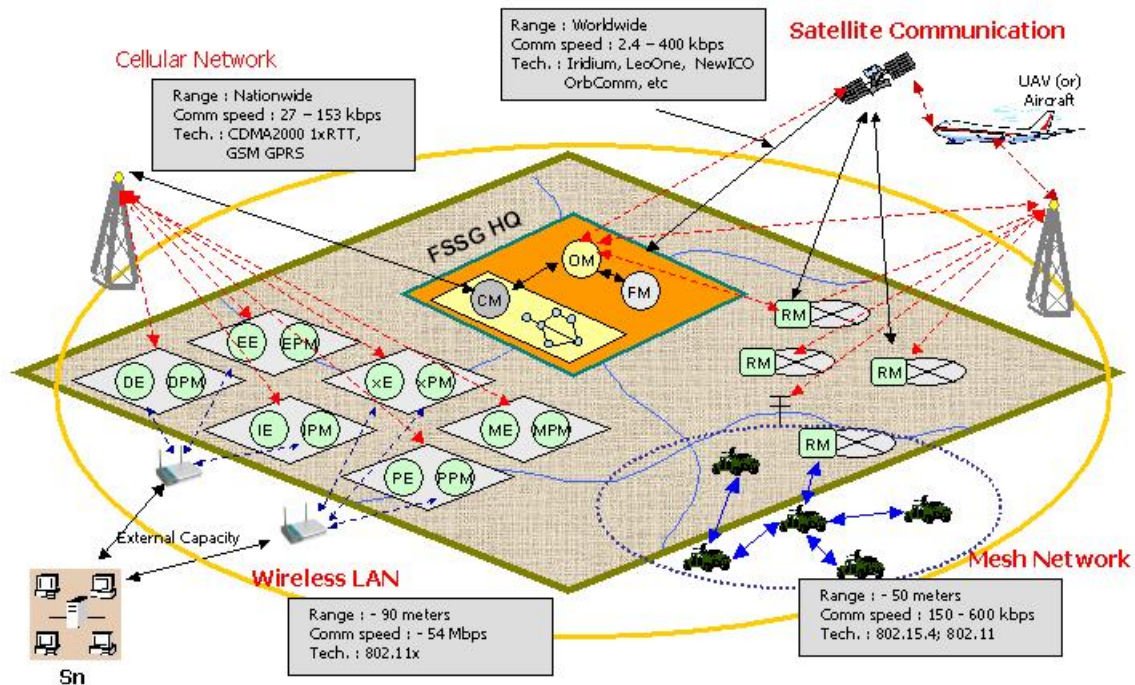
Figure 1.4: Global Operational Concept View

The supported units generate a request using handheld devices that are sent to the relevant supervising personnel for authorization. In a highly automated setup it is possible that onboard sensors could trigger a request. Once the request is approved, the information is passed onto the RM through a cellular network. The RM receives the request on a laptop computer, which prioritizes and processes the request. The data that is received is parsed automatically and the information is sent to the OM module in the form of an order. In case the resources are not available at the direct support then the order has to be fulfilled by OM using resources from other supporting units within the FSSG. The OM parses the order information and distributes the relevant data attributes to the specific CM. In case the OM and CM are co-located this communication can be done through a wireless LAN or by wired links. If they are farther apart the information can be transmitted through cellular networks. The capacity management personnel send a query to the production management seeking the availability of the resources. In case of a particular inventory item the availability is determined by querying the database where the inventory is stocked. The inventory database uses a

combination of wireless LAN as well as radio frequency identification (RFID) tags that are placed on the inventory items to keep track of their levels in real-time. The RFID tags uniquely identify the inventory item and eliminate the need for manual scanning as required in the case of bar codes. Once the availability is ascertained, this information is transmitted back from the laptop computer to the CM through the cellular network. Further the OM is also notified of the same. Once the availability of all the requested resources is ascertained, the OM directs the PM to reserve and prepare the products for pickup and delivery to the relevant supported unit. Reservation of a particular inventory item is done by modifying the information contained within the RFID tag to include details about the supported unit to which the item has to be sent.

The location of the transporting units is identified using a GPS satellite and an onboard GPS enabled device. The Distribution Production Manager (DPM) directs the distribution execution unit (DE) that is available and closest to the point of pickup to perform the specific distribution task. Work orders are sent by the PM to the distributing unit and the inventory execution personnel. These are received on the onboard GPS enabled device and the handheld device respectively. In case of the distribution unit the information is sent using the cellular network while the inventory execution personnel receives the work order through the wireless LAN at the inventory storage area.

During pick-up of the designated part the inventory execution (IE) personnel identifies the location of specific inventory item using the RFID tags and the wireless LAN. The items are loaded onto the respective vehicles the inventory database gets updated with the change in inventory level as the items get scanned when taken out of the storage area by a RFID reader. The distribution unit uses a navigation system onboard to help in routing it to the supported unit. At the supported unit the items are received and once again the tag is scanned using a mobile handheld reader, the receipt information is sent to the order management as a notification. The order is then closed, the details of transaction is sent to a centralized repository and can be used for further future analysis.

The above description that involve processing a request from the supported unit and fulfilling the request. In addition to this the OM function needs to maintain visibility of the assets to the Logistics Chain Planning (LCP) team and also needs to send procurement orders to Sn suppliers. This requires the need for long-range communication by the OM with different suppliers such as the sea-based logistics vessels, Defense Logistics Agency (DLA) and Fedlog. The range of transmission in this case plays a more important role when compared to the volume and frequency. Satellite communication thus can be used to enable such long-range communication in real-time. The inclusion of satellite communication will allow the supported and supporting units to remain connected to the different nodes in the absence of cellular connectivity.

The above description of a generic process of requisition and fulfillment shows the interplay of a number of technologies. Some of these technologies play a critical role in communication and asset visibility while others help enable the execution of different OA processes. We discuss these details in the next section. Figure 1.5 summarizes our technical solution to the OA processes.

1.5 Wireless Technologies Relevant to Operational Architecture

Because of the dynamic environment, mobility requirements of different units (supporting and supported units) and the variation in range of communication, a single wireless technology fails to enable all the processes. Moreover the reliability of communication and operations can be improved by adding sufficient redundancy in the means for communication. Given the context of OA, we have identified four different types of communication networks.
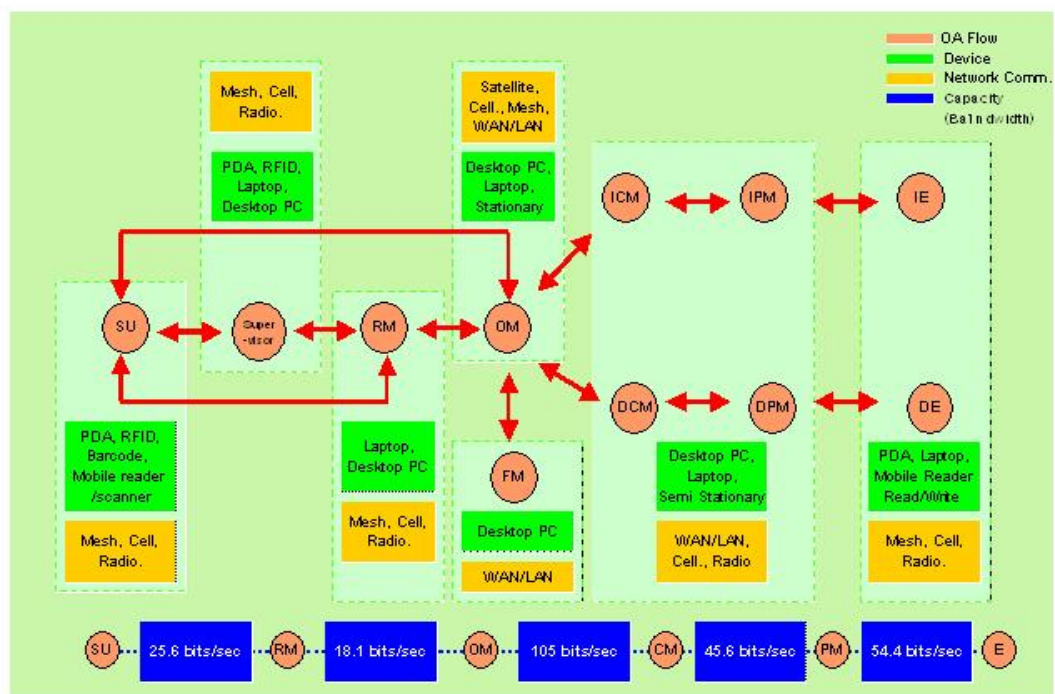
Figure 1.5: Technical Solution to the OA Processes

The mesh network allows users, embedded sensors and short-range radios to exchange information in a wireless environment without the need for a fixed infrastructure. Each user (or node), equipped with one or more sensors/devices, can move around while communicating with others. The path between any pair of users can traverse multiple wireless links and the devices can be heterogeneous, thus enabling an assortment of different types of links to be part of the same *ad hoc* network. The mobility of the nodes results in a network whose topology is dynamic. The network discovers the links between the mobile nodes and identifies paths so that any user can communicate with any other user, as long as each has a link to the *ad hoc* network. Within the *ad hoc* network, each node relays the data packets on behalf of others towards relevant destination nodes.

In the context of the USMC Operational Architecture these types of networks can be used for communication within the storage facilities specifically for the inventory execution processes. The RFID tags that are attached to the inventory items can use the mesh networks to transmit information to different devices (PDA, Mobile Scanners etc) that will be used by the IE personnel. Mesh networks need to be used for sensing health information of the ground equipment by embedding sensors. This will enable automated transfer of health information to the maintenance execution (ME) personnel when the equipment is ready for inspection. Mesh networks can also be used as a backup for short-range communication in the absence of connectivity to a cellular network or wireless LAN.

In addition to the mesh networks the wireless LAN need to be used to add redundancy and enable secure connectivity within relatively static environments. These networks use an access point to which most of the users connect their devices. Using a wireless LAN within the storage facilities will allow the IE to access the inventory database and receive work orders while they are moving. The emerging technology in this area using IEEE 802.16 technology will allow communication within a one-mile radius. These networks will also allow the ME personnel to communicate with the Maintenance Production Manager (MPM) when they are within their work environment. Similarly the Distribution Execution (DE) personnel can communicate with the DPM using wireless LANs. Thus the wireless LAN technology can enable communication between the different execution units with the corresponding production units.

The desired communication range between other nodes within the operational architecture such as RM to OM and OM to PM are much larger than what can be covered by the Wireless LANs. Therefore these transactions need to be transmitted using cellular networks. These networks use different mobile base stations equipped with appropriate mobile switching stations to enable long-range communication. The coverage achieved by these networks is dependant on the number of base stations that are available in the region of interest.

Satellite Networks should be used to enable the OM to communicate with Sn suppliers. These suppliers may be present in entirely different region on the globe. Satellite communication provides worldwide connectivity but the available bandwidth is limited compared to the cellular networks. In the context of the operational architecture the communication between OM and the Sn is done mostly for procurement/replenishment purposes and so the expected frequency of orders is relatively low. Therefore satellite communication can be used between OM and Sn. Table 1.1 lists the wireless solutions to the OA Processes.

Table 1.1: Mapping Wireless Solutions to OA Processes

OA Nodes	Task / Process	Requirements	Wireless Technology
Execution (E)	Item identification	Devices: RFID Scanner capability to reprogram	- Mesh Networks wherein individual nodes are specific RFID tags
	Receiving Work Orders	Devices: PDA	- Wireless LAN connecting different PDAs to the IPM server
	Loading for distribution	Devices: Fixed RFID scanner that can read the items that are leaving the Storage facility	- Wireless LAN connecting the scanner to the inventory database at IPM
Capacity management (CM)	Verify resource availability	Devices: Web server with wireless connectivity to different DPMs	- Cellular Network
	Reservation of resources	Devices: Webs server that maintains connectivity to the IPM server	- Cellular network or satellite communication
	Communication with OM	Short range communication if CM and OM are co-located	- In case of short-range communication this can be achieved through wired LAN if mobility is required Wireless LAN can be used.
Production Management (PM)	Reservation of items	Devices: web server/ wireless LAN access point	- The notification to reserve items can be sent to the execution units through WLAN
Request Management (RM)	Receive requests in real-time	Devices: Laptop	Cellular network connectivity to different supporting units is required
	Return of inventory	Devices: RFID scanner with read write capability	Mesh network
Order Management (OM)	Procurement	Devices: Web server	Satellite communication is required to allow long range communication with Sn

1.6 OA Processes to Be Enabled

The notional description and Table 1.1 map the different enabling wireless technologies to different OA processes. Within the OA processes the critical segments that need to be enabled with wireless solutions are listed below. These form the main areas of focus for the USMC to proceed towards implementation and testing.

- Enable real-time requisitioning by implementing cellular communication between supported units, RM and OM
- Reduce the time to respond by enabling wireless communication between execution units and Production Management
- Increase asset visibility by identifying inventory items using wireless LANs and RFID mesh networks
- Use satellite communication as a backup to increase reliability in communication
- Enable intelligent preparation of the battlefield for logistics

1.7 Recommendations

We recommend that the USMC generate a strategic plan for proceeding towards implementation. To support this near term steps should include the following.

Develop a prototype to guide implementation of wireless solutions for the OA processes identified in section 1.6. This requires enhancing and refining the proof-of-principle system that has been developed. The reliability of the wireless solutions needs to be tested in field environments. The specific decisions support tools have to be defined and developed. In addition the system specifications should be refined along with performance metrics. The organizational impacts of implementing these wireless solutions have to be analyzed within the context of tactics, training procedures and manpower.

1.8 Organization of the Report

This report is organized into eight chapters. Each chapter provides information about specific tasks that were assigned to the PSU team. Figure 1.6 shown below maps the tasks to the relevant chapters.
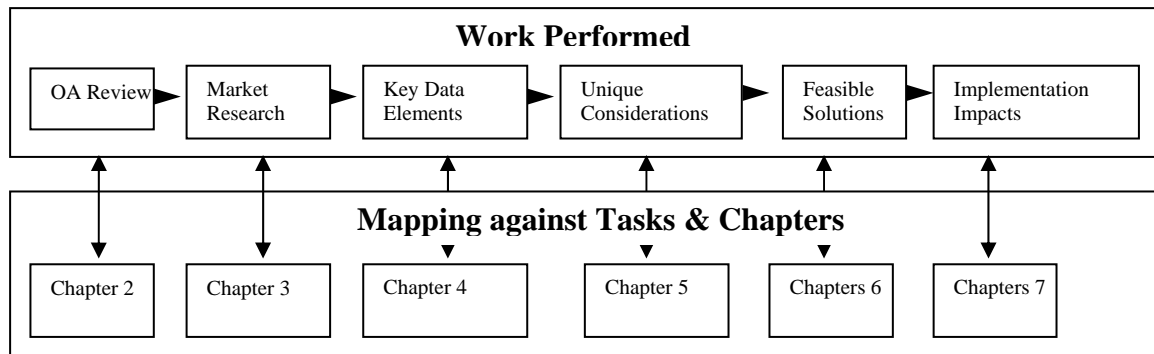
Figure 1.6: Structure of the Report

1.9 Credits and Acknowledgments

The study benefited considerably from contributions by the following individuals:

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GySgt William Cowger

Marine Corps Logistics Depot at Albany, GA
Ms. Pat Shaw
Mr. Randy Geoghagen
Capt Jake Enholm

2 Review OA Processes and Performance Measures

<u>Task 1: Review OA processes and performance measures</u>
1.1 The sponsor shall provide reference materials and training on the OA to Penn State personnel. The materials and training will facilitate an understanding of the OA that will permit insight into those areas suitable for portable/wireless technology implementation.

1.2 The sponsor shall assist Penn State in compiling/reviewing any previous studies or other ongoing DoD portable/wireless technology initiatives.

The team reviewed the OA for the "To-Be" logistics enterprise for the Marine Corps. The information supplied by the sponsors presented a high-level conceptual view as well as a detailed description of the proposed operational architecture. A thorough review of the literature helped the team identify the information flow the data requirements and specific processes that need to be enabled using wireless technologies and possible portable devices. The team also reviewed commercially available solutions and best practices to identify how these systems can be used to enable specific processes within the OA. A brief description of both the conceptual view of the OA and the functional process flows that were identified is presented in the following section.

At the conceptual level the OA is a set of standard processes to be used across the logistics enterprise that were developed by the USMC Integrated Logistics Capability (ILC) team. The OA is based on ILC concepts and commercial best practices. The high-level OA serves as the foundation for the follow-on efforts to develop the detailed OA for GCSS-MC. This section on OA is organized to discuss the OA at a higher level of abstraction followed by a detailed description.

2.1 Scope and Approach of OA
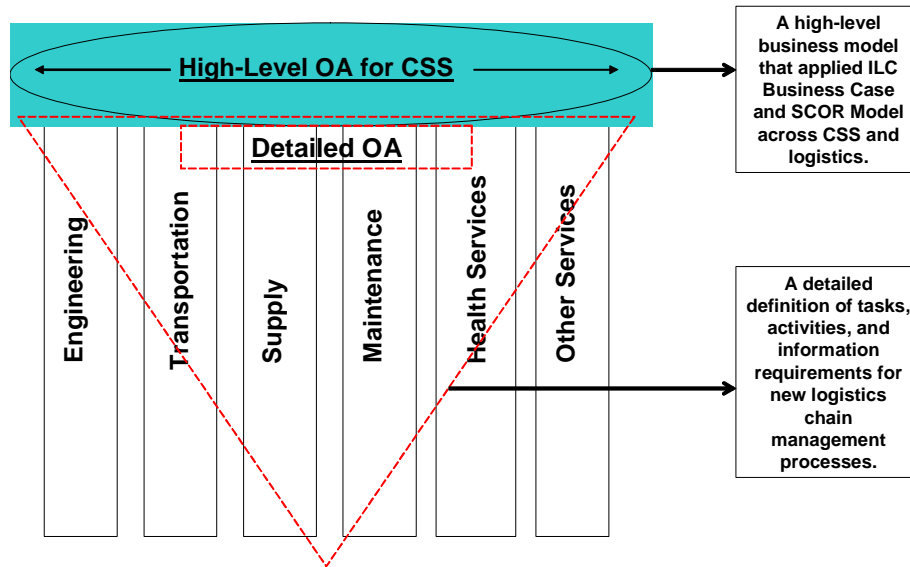
Figure 2.1: OA Scope and Approach

The high-level OA breaks down into the detailed OA where tasks, activities, and information requirements for new logistics chain management processes are defined. The high-level view of the Marine Corps logistics chain reflects characteristics that are similar to the typical supply chain existing in commercial enterprises. For example, a typical commercial supply chain is comprised of two basic sets of activities –recognition of demand for products and services, and the fulfillment of that demand. The Marine Corps logistics chain can be described in these terms. The consumer creates demand for products or services, and a supplier fulfills that demand. Despite the similarities between the two, the Marine Corps logistics chain differs from the commercial world. These differences are directly related to the organization, roles, and mission of the Marine Corps.

Based on the high-level OA and the SCOR Model context-specific detailed OA processes were identified. The SCOR Model outlines the steps of a logistics chain transaction, starting with the consumer inquiry through the paid invoice. The Pennsylvania State University (PSU) team has used the OA as the foundation for identifying the optimal wireless technologies and the portable devices that can be used to enable the futuristic logistics system.

2.2 Review - High Level OA
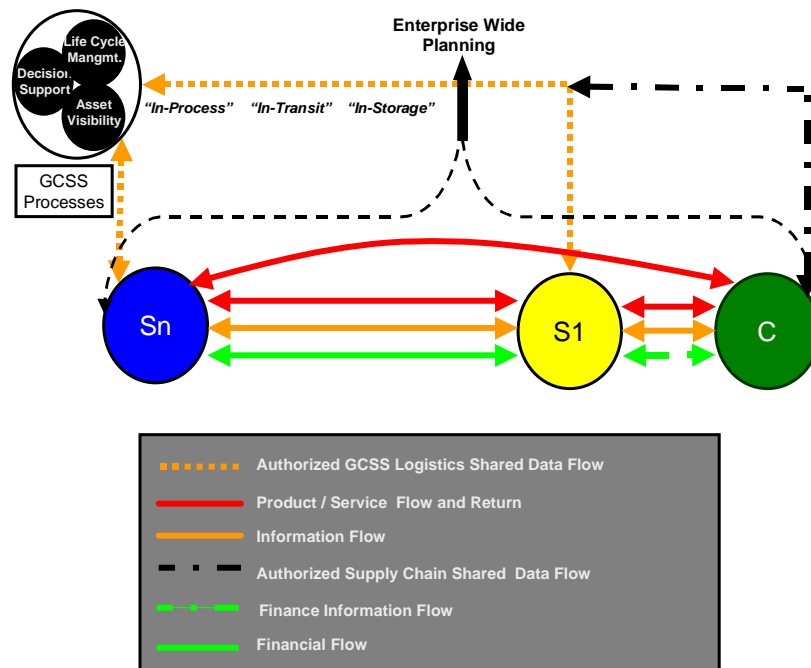
Figure 2.2: High-Level Operational Architecture

The Customer in the "To-Be" logistics chain is defined as the ultimate consumer of products and/or services, such as a supported unit, and is depicted as "C" (Figure 2.2). The consumer is responsible for generating demands, conducting operator level maintenance, and accounting for resources. Demand may be reactive (e.g. unscheduled maintenance), or forecasted (e.g., scheduled re-supply), using manual and or automatic (e.g., autonomic) modes of communication. The key feature in the proposed architecture is that the consumer demands/requests are passed to a single entity. This entity is depicted as Supplier 1, or the "S1" node. Supplier 1 is responsible for all logistics chain processes including order management, sourcing and the delivery of products and services for the consumer. Its primary obligation is to fulfill the demand generated by the supported units, not necessarily to maintain a hierarchical relationship between itself and its supplier(s). It maintains inventory and asset visibility, has intermediate maintenance capabilities, and conducts financial management for the supported units.

The supported units communicate demand for products and/or services to Supplier 1 by any available means. The orange (middle) arrow in Figure 2.2 depicts the information flow. This link is the Consumer's interface with the logistics enterprise and includes other information such as order receipt, order status, and shipping information. Demand signals from the consumer lead ultimately to the flow of products and services up and down the logistics chain.

Supplier 1 is responsible for communicating with all other suppliers, vendors and service providers (called Supplier(s) N, and depicted as "Sn"). Supplier(s) N replenishes demand generated from the Consumer at the request of Supplier 1. Within the Marine Corps, Supplier(s) N activities include (but are not limited to) wholesale supply, depot-level maintenance, and management of secondary repairables. In addition, Supplier(s) N's involvement with the logistics chain enterprise is based on its relationship to Supplier 1. Examples of Supplier(s) N include the Defense Logistics Agency (DLA), clinical health care provided by the Navy, transportation services provided by Transportation Command (TRANSCOM) via Global Transportation Network (GTN), commercial vendors, authorized civilian agencies, or even adjacent units.

2.3 Review - Detailed OA

The agreed functional areas and flows assessed in Figure 2.3 are described below and shown in detail in Appendix 10.3, Chapter 3 Interim Report 1.
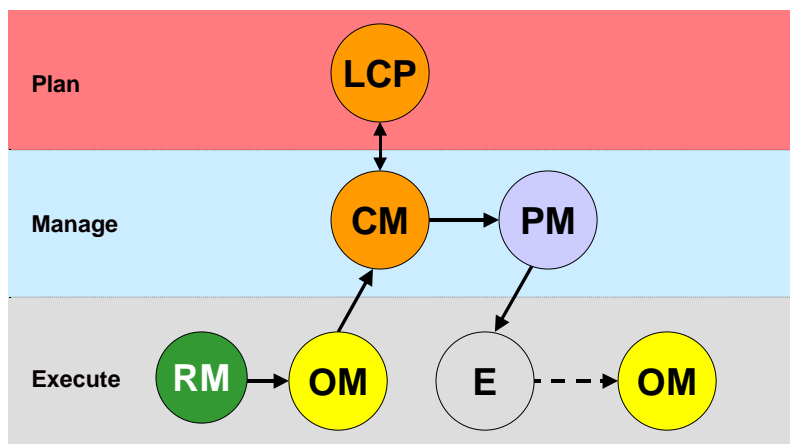
Figure 2.3: High-Level Functional Context Diagram

Logistic Chain Planning (LCP) is located in the enterprise level. The duty of LCP is planning and designing logistic chain to fulfill customer's demands.

Request Management (RM) is the function for generating and approving customer demands. Basically, it works by validating customer requirements and generating requests for logistics support (fulfillment of products and services) if required. RM receives requirements from within the customer / supported unit; prioritizes requirements, sources the demand internally or processes the requirement into a request and submits the request to be created into an order.

Order Management (OM) is the function for routing, coordinating, tasking, and tracking customer orders through fulfillment. This function works by receiving requests from customers, generating customer orders (based on requests) and initiating the fulfillment of products and services. In addition, OM processes communicate order status to the customer.

Capacity Management (xCM) is the function that involves managing, optimizing, prioritizing, and planning resources and capacity to fulfill customer demands. It can be divided into 4 categories (Distribution, Inventory, Maintenance and Procurement indicated by x as appropriate). Each category can again be divided into other sub-categories.

Production Management (xPM) is the function for coordinating, planning, tasking and controlling how customer demands are fulfilled. It can be divided into 4 categories (Distribution, Inventory, Maintenance and Procurement). Each category can then be divided into other sub-categories.

Execution (xE) is the function for executing CSS tasks to fulfill customer demands. It can be divided into 4 categories (Distribution, Inventory, Maintenance and Procurement). Each category can be divided into other sub-categories.

The detailed review of the OA was performed at the beginning of the study and the relevant documentation can be found in Appendix 10.3, Interim Report 1. Table 2.1 depicts the list of all the processes that were reviewed.

Table 2.1: List of OA Processes Reviewed

Sr. No.	2.3.1.1 Functional Process Flow
1	Request Management – Product
2	Request Management – Return
3	Request Management – Service
4	Order Management – Product
5	Order Management – Return
6	Order Management – Service (Distribution)
7	Order Management – Service (Maintenance)
8	Customer Service Management
9	Logistics Chain Planning – Back End
10	Logistics Chain Planning – Front End
11	Network Design Planning
12	Customer Service Planning
13	Life Cycle Management
14	Maintenance Planning
15	Maintenance Allocation Planning
16	Procurement Planning
17	Demand Planning
18	Inventory Planning
19	Return Planning
20	Capacity Management – Inventory
21	Capacity Management – Maintenance
22	Capacity Management – Distribution
23	Capacity Management – Procurement
24	Production Management – Inventory
25	Production Management – Distribution
26	Production Management – Transportation
27	Production Management – Inventory
28	Production Management – Maintenance
29	Production Management – Procurement
30	Execution – Distribution
31	Execution – Inventory
32	Execution – Maintenance
33	Execution – Procurement

3 Market Research

Task 2: Market research and processes to be enabled

2.1. A market survey will be conducted of (current) COTS and (future) developmental portable/wireless technologies that are/could be available to support the OA.

2.2. Based on an understanding of the OA and input from the Sponsor, identify those OA processes, which will benefit from COTS/developmental portable/wireless technologies. The identification of OA processes will be based on metrics to be mutually agreed upon between Penn State and the Sponsor. This task will assist in limiting/defining the scope of the study.

This chapter briefly describes the different commercial supply-chain practices that were reviewed. The key areas that were focused on were managing orders, tracking inventory and supply-chain performance evaluation. The sections below summarize the findings of the PSU team. Detailed description of the various commercial industries that were studied is presented in Appendix 10.3 Interim Report 1.

Wireless applications for logistics management in the USMC have several parallels in the private commercial sector. With this said, it must be noted that the primary uses of wireless in the commercial sector is for inventory tracking and asset visibility using RFID technology.   The report in Appendix 10.1 highlights the wireless environment, focusing primarily on the RFID portion. This present section of the report highlights some specific applications and technology solutions that might be appropriate for USMC consideration.   The reader is referred to the appendix for the detailed discussions of specific commercial applications.

3.1 RFID Solutions for USMC Applications

In the USMC OA, primary communication occurs between the RM and the OM to determine needs. The OM then transmits further information to the CM, who in turn works with the PM, who then translates the request for final execution (E). In garrison, these communications can be managed through centralized, robust databases and a combination of hard wiring and wireless technology. Figure 3.1 highlights these communication channels.
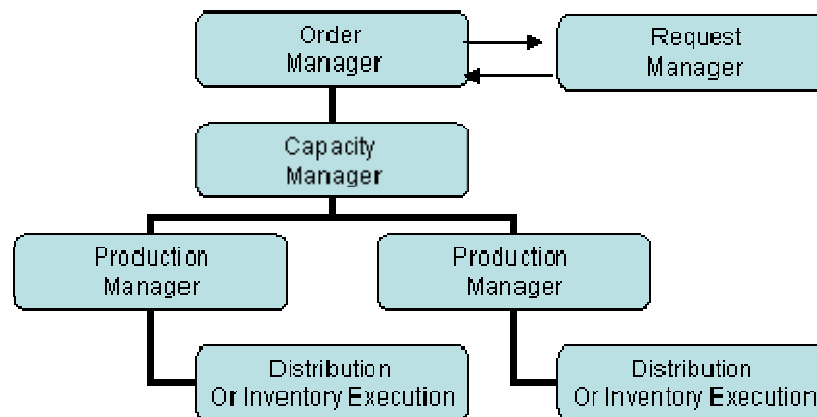
Figure 3.1: Communication Channels in the USMC OA

In the theatre, however, these communications must have more redundancies built into them to accommodate a less than seamless connection between the individual nodes and the centralized information. The current effort does not address these multiple channels. Instead, it offers two solutions using RFID and associated wireless technology to increase *asset visibility across the logistics chain* and to *facilitate maintenance production.*

3.1.1 Asset Visibility

In the commercial sector, the primary use of wireless technology it to increase asset visibility across the supply chain, including during production. This is dominated by the use of RFID tags that replace many of the manual tracking systems and enable real time management and tracking of assets. The RFID tag, whether it be item-level, case level or pallet level, can be read by a fixed or mobile reader which sends the tag's information to a centralized (generally) database for further query as needed. These tags, linked directly to the centralized system, help initiate advanced shipping notices as inventory is prepared for distribution. Then, throughout the logistics chain, inventory can be tracked geographically to determine where in the supply chain it resides at any point in time. A complete description of RFID technology and specific commercial applications appears Appendix 10.1 entitled, "Wireless Applications for Supply Chain Management – Report of Commercial Applications and the Implications for U.S. Marine Corps Logistics." The full report in the appendix not only summarizes commercial applications, but it also highlights recommendations specific to the use of RFID to increase asset visibility.

The current material stresses a strategic-level discussion of RFID deployment for asset visibility rather than tactical considerations. For tactical recommendations, the reader is referred to Appendix 10.1 where 20 tactical recommendations are presented. The granularity of these recommendations is deferred in the present discussion.

From a USMC OA perspective, RFID solutions affect the distribution execution and the inventory execution portions of the OA. This is an enabling technology that can replace many manual operations if fully implemented.

Figure 3.2 shows the differences between the stateside and the in-country inventory receiving, tracking and distribution systems. In both cases the end user (at the right hand side of the figure) originates a request for supply that is handled by the S_1 node, a combination of activities for OM and RM. As noted earlier, the OM then cascades orders and coordination downward to execution.

In considering technology solutions, at issue are two different types of flows: information flows and material flows. Figure 3.2 highlights both as suppliers receive orders, fulfill them and then send them out to the end user via established depot locations at the USMC. These depots may be in fixed locations (stateside) or may vary depending on MEF locations in country.

It should be noted that the centralized databases supported in garrison should have strong parallels to the databases that support deployed (In-country) distribution centers. The specifics of this architecture are beyond the current report, but logistics management deployed should be limited to one repackaging/relabeling activity rather than continuously relabeling throughout transit to the end user. Typically, USMC operations transport to the deployed location based on efficiencies of transportation, and items are not packaged based on their end-user destination. This requires some repackaging from the shipped containers to pallet level, and sometimes to item level for critical supplies.

From a supply perspective, there are critical differences between the garrison and the deployed in theatre that will impact the choice of RFID technology and wireless communications. Within the garrison, communication channels are well established and thus stable. Robust centralized database management is combined with readily available distributed computing. In addition, incoming and outgoing materials move through fixed portals, and into relatively predictable transportation channels (roadways, railways). In contrast, deployed operations can be characterized by dynamic communication channels, with inventory tracking and distribution being only one of several items that must be managed within the battlespace that has fixed communication capacity at any given time. Distributed computing is available, but is remote and linkages to centralized databases are inconsistent and must be balanced with other communication needs. Portals for incoming and outgoing materials are flexible, and will change with the MEF location and the particular staging area. Thus business rules that work well in garrison will not necessarily be flexible enough (or robust enough) to accommodate these deployed differences.

All of this suggests that a hybrid solution might be needed to fully accommodate asset visibility within the USMC. Figure 3.3 highlights the material flows and

information flows that could be RFID enabled. The specific communication of the RFID information can be wireless or hard wired, depending on location. Note that fixed location RFID readers are combined with mobile, handheld readers to increase asset visibility, particularly forward logistics deployed.

Asset visibility throughout the logistics chain suggests that a strategy that maximizes information capture while minimizing repackaging in the field and balancing visibility with inconsistent field communication will be needed.   Based on this, in garrison, RFID solutions can be simpler (passive read only) tags with much of the data stored in a centralized database. Forklift readers can be used to identify the location where a particular container or bin has been placed and that container/bin can then be associated with its contents in a database.   A commercial solution like this can be seen at the ES3 distribution center, which uses Whernet technology/software.
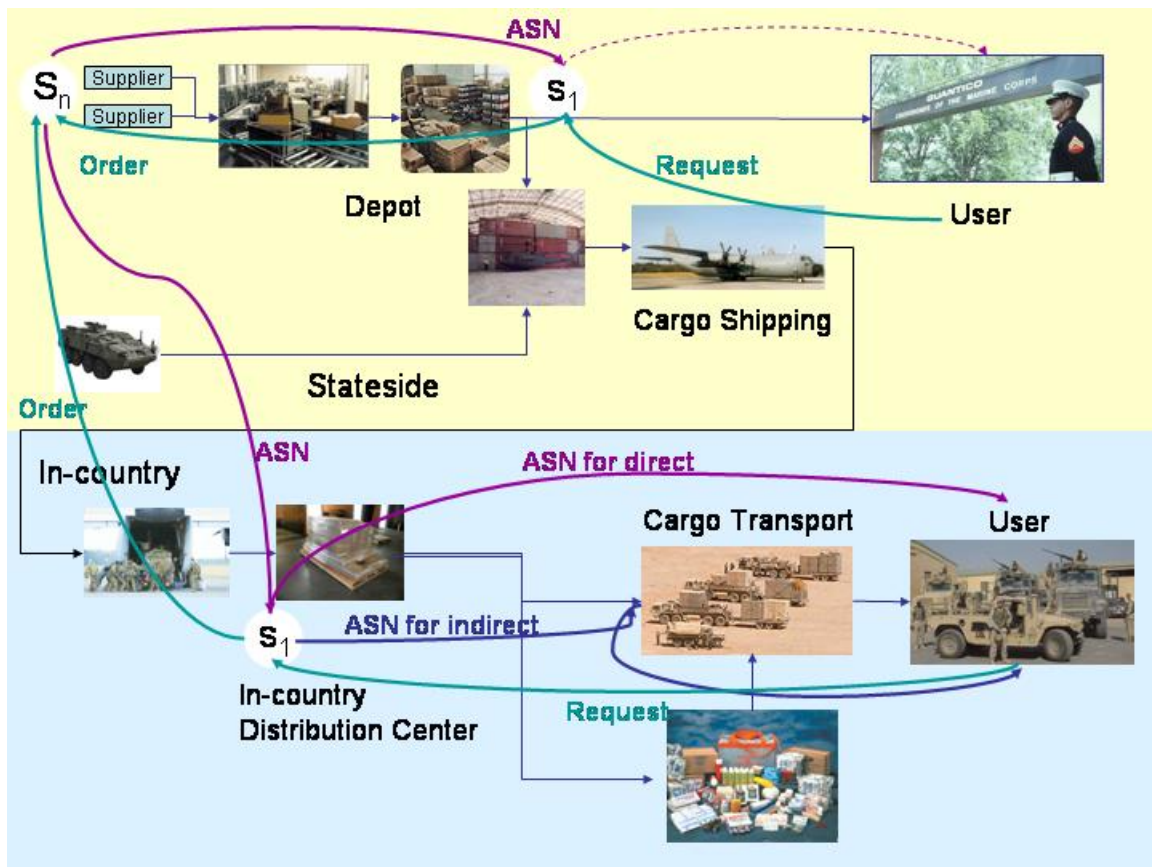
Figure 3.2: Stateside and In-Country Inventory Distribution
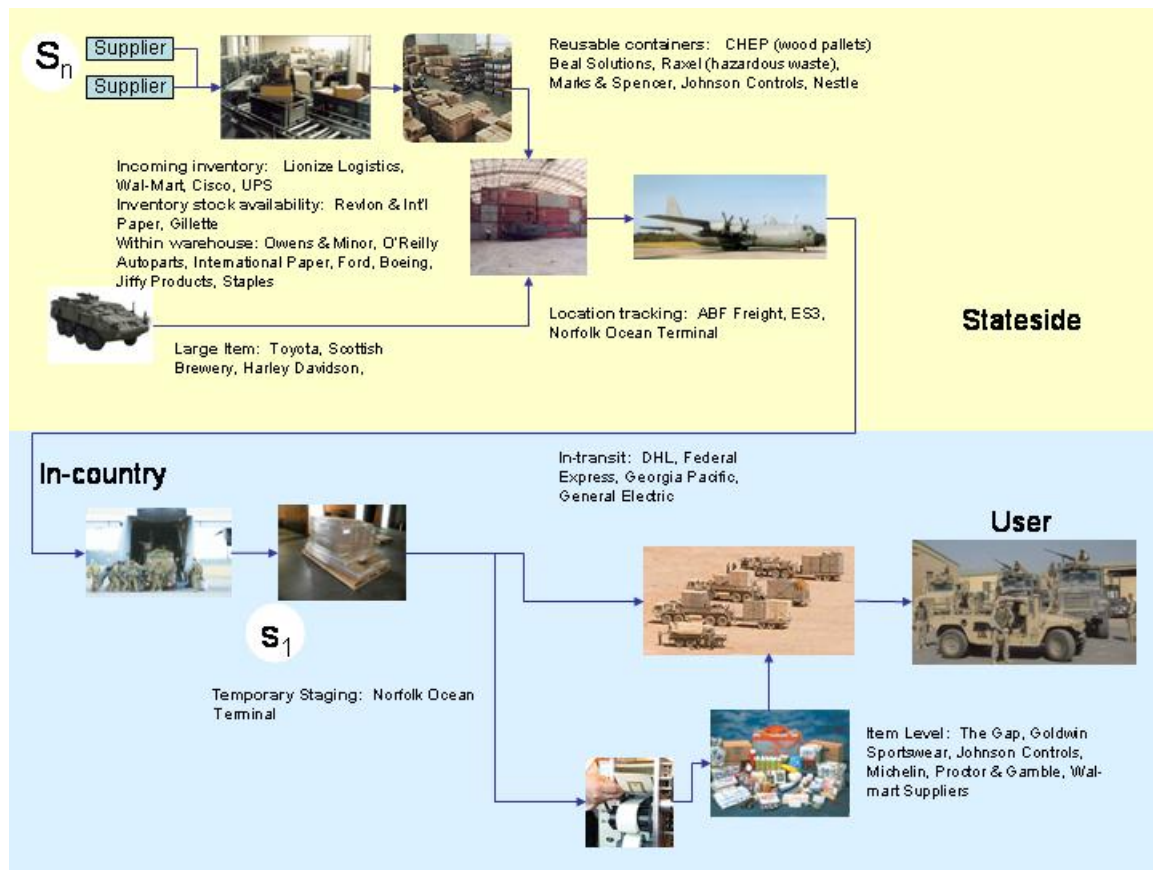
Figure 3.3: Asset Visibility for MEF Re-supply

In theatre, a more robust RFID must be employed earlier in transport, with tags of a read-write variety to facilitate bundling in containers, and then repackaging and distribution later in forward deployment in-country. The higher function tags will be required to balance inconsistent connectivity with on-the-ground asset visibility. Portable readers will also help identify contents of containers.

Related to asset visibility is the tracking of specialized containers/packaging for equipment. This is important both for forward deployment and for return maintenance or retrograde. Commercial tracking of specialized or reusable containers includes tracking of containers during production (detailed in the next section), hazardous material containers, kegs and internal transport containers. These are presented in detail in Appendix 10.1, Table 10.

3.1.2 Maintenance Production & Operations

A second use of RFID for USMC applications might include the tracking of return logistics for repair or retrograde, as well as maintenance production. This is analogous to commercial activities in manufacturing where containers are tagged with read-write tags that relate to the contents of the container and the processes

that must be done on the material inside. Generally related to a build-to-order manufacturing strategy, Ford, Johnson Controls, Harley Davidson, Nestle, Boeing, Toyota and General Motors all use RFID tagging to link the inclusion of specific features with a particular order. For example, Johnson Controls uses read/write and read-only tags to convey information about product seat configurations and to identify specific testing procedures that must be done to fully qualify the product.   Specific manufacturing approaches are detailed in Table 10 of Appendix 10.1.

A USMC analogy to this is maintenance where larger scale pieces must be maintained and refurbished. During maintenance production, RFID tags could be linked to specific procedures that are needed for a particular repair. The RFID tag information is then associated with a centralized database that details procedures, part requirements, and perhaps technician skills.   The tag is prepared at the MPM level, and during execution, it is read at a workstation to guide the repair technician.

From a remote perspective, Sears has taken this one step further, by using wireless communications to facilitate planned and emergency maintenance/repair scheduling. This workforce scheduling system updates field technician assignments as new repair requests are received. Sears uses this system to keep its remote workforce continuously updated about service repair needs which are coordinated at a Sears centralized call center. The automated system includes repair requirements and matches them to technician skill sets that are also centralized stored.

Such a remote scheduling system, combined with RFID tracking of maintenance inventory needs could promote equipment health in the battlespace by more rapidly deploying a skilled technician to a particular location with the necessary parts. To accomplish this, likely repair problems would have to be matched to standardized inventory needs for that repair as well as the needed skillset to accomplish the repair.

Related to maintenance production management and execution, RFID technology could facilitate in-the-field diagnostics of problems that must be shipped to another area for repair. This could be done in two ways: (1) tracking of the location of specialized containers/packaging to return the damaged item; and (2) RFID read-write tags associated with the item that indicate initial problem diagnosis.   This would enhance the response time for maintenance since problems might not need to be diagnosed twice (once in the field and then again at the repair site).   This could also help maintenance facilities schedule more effectively by automatically linking incoming repair problems with likely inventory needs and skillset needs. Such triage could enable anticipatory planning in the backward portion of the maintenance chain based on diagnostics performed in the forward deployed location.

A specific parallel to this USMC need is not apparent in the commercial sector at the present time, but could be adapted based on automated maintenance scheduling, reusable container tracking, and manufacturing RFID practices. Further work is needed to identify specific operational maintenance needs for the USMC before recommending specific approaches.

3.1.3 Summarizing Commercial Applications Related to USMC Needs

Figure 3.4 summarizes analogous commercial applications as they relate to USMC asset visibility and maintenance production needs.   No single commercial application embodies the full needs of the USMC and a direct off-the-shelf transfer of technology from commercial to USMC is unlikely.   Moreover, best in class is difficult to determine since RFID technologies are still in pilot stages of roll-out.   Instead, this figure highlights companies undertaking RFID implementations related to specific material tracking activities.   Full details of these implementation projects and their features can be found in the appendix.
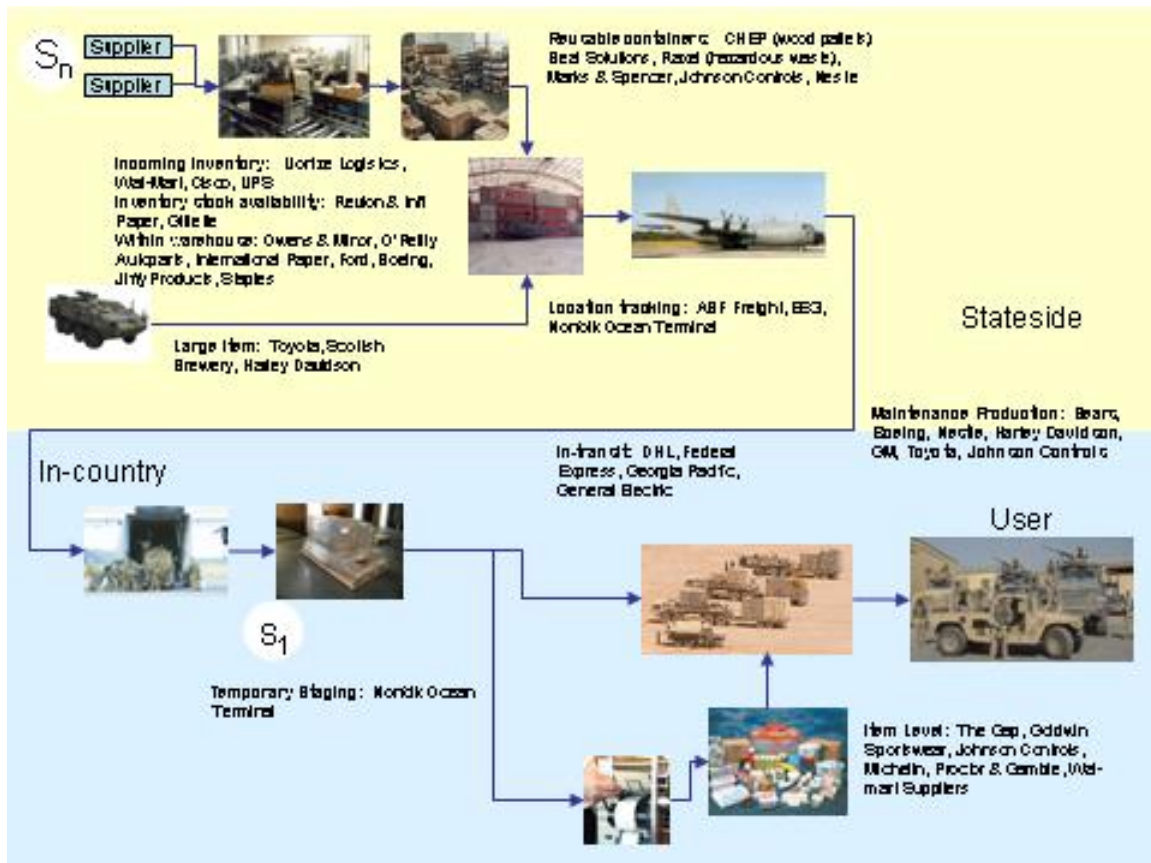
Figure 3.4: Commercial RFID Material Tracking

3.1.4 Implementation Issues

Though not specifically part of this effort, some implementation issues that have constrained the effectiveness of RFID technology solutions in the commercial sector might offer insight to the USMC as it moves forward.

Early implementation programs suggest that human error is much more problematic than anticipated. The technology is still sensitive enough to positioning and other human-handling issues that robust business rules will be needed.

After a pilot problem with item-level tracking, Wal-Mart, the key commercial RFID player, has focused its near term efforts on pallet level tracking at its distribution centers. This gives the USMC an early opportunity to learn about the feasibility of RFID to enable and enhance palletizing and packaging for further distribution at remote locations. Here the analogy is between Wal-Mart distribution centers and its stores, with goods shipped by truck to a USMC distribution channel that includes depots to MEF staging areas via container shipping. Packaging and redistribution of goods in theatre is currently difficult since USMC goods are packaged stateside to take advantage of transportation efficiencies, with little attention paid to the distribution logistics during forward deployment. This suggests that there might be two distinct USMC forward deployment needs: initial deployment where massive numbers of tons of equipment, supplies and personnel must be moved, and re-supply of a MEF already in theatre. Re-supply might resemble the Wal-Mart activities more closely than initial deployment. Further work is needed to determine whether or not this is the case.

Technology interoperability remains a challenge for readers, tags and geographical communication differences. Though several standards bodies are actively engaged in developing protocols that can be broadly adopted, to date, this remains an issue. Because of this, it is not possible, nor prudent, for the USMC to expect that it can combine best in class readers with best in class tags. Readers and tags must be matched. Some experts have predicted that it will not be until 2006, approximately two years after standards emerge this summer that interoperability issues will be overcome.

The expertise needed to implement RFID systems does not currently exist in great enough quantity to staff commercial and military applications. This results in some basic misconceptions about the technology and its safety. In addition to needing robust USMC business rules, the USMC should also consider worker worries about prolonged exposure to radio frequencies. Though it has not been proven harmful to date, early installations suggest that worker comfort is increased with exposure monitoring devices.

4   Identify Key Data Elements and Information

Task 3: Identify key data elements and information
3.1 For each process identified in Task 2, identify the key information required for both the execution and performance measurement of the process to no lower than SCOR Model Level 4 logistics support.

4.1   OA Use Cases

Based on the review of the OA and the feedback from the sponsors the PSU team identified specific processes to focus on. These were represented in the form of use cases. The use cases generated represent five major operational elements -RM, OM, CM, PM and E. The functional areas considered are: Supply (Order fulfillment) services, Return services, Maintenance services, Procurement services, Distribution services, Health services, Engineering services and Customer service. Each functional area along with its sub categories is shown in Figure 4.1.
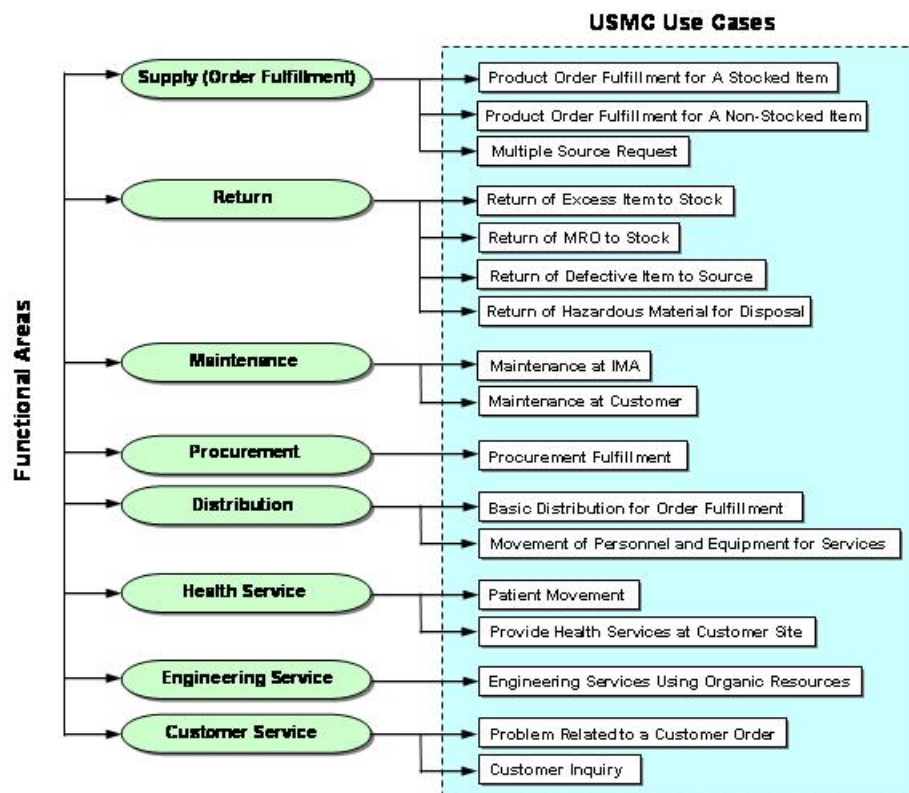
Figure 4.1: Functional Areas of OA and Sub Categories

4.2 OA Data Elements and Information Flow

Details with regard to each of the use cases were added using information flow diagrams and the node-to-node communication were represented in the form of tables. Each table represents a single use case and one such example for the use case *Return of MRO to Stock* is shown in Table 4.1. These tables comprise the following details

- Speaker – Process originating a particular communication
- Listener – The destination module, where the information is received
- Performative – The action intended to be performed for a particular communication between two nodes [Kumara et al., 2003]
- Attributes – Data elements that are transferred during communication
- Medium - The required mode of communication (for example voice, text, image, form etc.)

The above terms were considered from the Knowledge Query Manipulation Language (KQML).

Return of MRO to Stock

Supported unit identifies a need for a product return due to MRO (Garrison or Deployed). Product is a cataloged item.

Table 4.1: Return of MRO to Stock

Step	Speaker	Listener	Performative	Content Description	Attributes/ Media	Descriptions
1.1	Supported Unit	Supervisor	Ask	Inform the requirement to put away/return the items from local inventory to the stock. Ask supervisor for validation.	Unit Identification, NSNs Quantity, Location, Expected time for replenishment. - Text, Digital, Voice	The request could be sent as an e-form. The location information is identified by the GPS enabled device and sent along with the form. The voice acts as a backup for human to human.
1.2	Supervisor	RM	Inform	After accepting the need to return the items.	Secure signature - Encryption	Usually password encrypted.
2.0	RM	OM	Inform	Submit and inform about the requirements on behalf of the using unit.	Request Identification + 1.1 - Text, Digital	In addition to the request form a request ID is automatically generated by the system which would be some digital information.
3.1	OM	MCM	Ask / Accept	Ask the availability of resources (Tools and man power) and MCM either accepts or rejects.		
3.2	MCM	OM	Accept			
4.1	OM	ICM	Ask / Accept	Ask the availability of resources to receive the product.		
4.2	ICM	OM	Accept			
5.1	OM	DCM	Ask / Accept	Ask the availability of the Transportation for the pick up of products from the using unit and DCM accepts or rejects it.		
5.2	DCM	OM	Accept			
6.1	OM	MCM	Ask / Accept	Assess the capability of MCM to make the repair within the relevant conditions of time.		
6.2	MCM	OM	Accept			

Continued Table 4.1: Return of MRO to Stock

Step	Speaker	Listener	Performative	Content Description	Attributes/ Media	Descriptions
7.1	OM	ICM	Ask / Accept	Assess the availability of resources at ICM to receive the product within specified conditions.		
7.2	ICM	OM	Accept			
8.1	OM	DCM	Ask / Accept	Assess the availability of the Transportation for the pick up of products from the using unit and DCM accepts or rejects it		
8.2	DCM	OM	Accept			
9.0	OM	Supported Unit	Inform	Confirm with the Supported unit by reiterating the requirement and the terms and conditions for pick up and repair.	Request ID confirmation - Text (short message) Voice	Confirmation of the request can be achieved by sending the request ID back and forth with the customer.
10.1	OM	FM	Ask / Accept	Optional – In case funds are to be credited for the return then OM asks FM about availability of the funds.	- Text, encryption, digital.	The total cost repair is presented as an e-form. It is encrypted and sent for confirmation of availability of funds.
10.2	FM	OM	Accept			
11.0	OM	MCM	Inform	Inform MCM to reserve and schedule the resources.		
12.0	OM	DCM	Inform	Informs in advance the need for distribution capacity for the products to be returned.		
13.0	OM	ICM	Inform	Informs in advance the need for resources to receive the product.		
14.0	MCM	MPM	Inform	Inform MPM to reserve and schedule the resources for fulfilling the repair.	Order ID, NSNs - Text, Voice	The specific list of resources is sent so as to enable the IPM to reserve the resources.
15.0	MCM	DCM	Inform	Inform the relevant shipping requirements.		
16.1	MCM/ DCM	DCM/MCM	Inform / Accept	Coordination for pick up.		
16.2	DCM/MCM	MCM/ DCM	Accept			
16.3	MCM	OM	Inform	Signal the delivery requirements.		

Continued Table 4.1: Return of MRO to Stock

Step	Speaker	Listener	Performative	Content Description	Attributes/ Media	Descriptions
17.1	MPM	ME	Inform	Assigns the resources from the execution element for this particular task.	Work order ID, Item ID - Text, Voice	Generated work order is sent to the ME so as perform the required tasks.
17.2	ME	MPM	Accept			
18.0	DCM	DPM	Reserve	The specific resources are reserved.	Transporting unit ID, Time to pick-up, Location - Text, Voice, Digital	The identified products are listed out and sent.
19.1	DPM	DE	Inform	Place a work order for the pick-up from using unit and delivery to the MCM of the products to be repaired.	Item ID, Location, Destination location - Text, Voice	The location from where to pick-up the item and product lists are sent using the e-forms.
19.2	DE	DPM	Accept			
20.0	OM	Supported Unit	Inform	Inform the Supported unit to stage the product for pick-up by DE.	Signal -Text (Short message), Voice	Message asking the using unit to stage item.
DE now picks up the staged product from the supported unit and delivers it to the assigned ME unit.						
21.1	DE	DPM	Inform	Inform the delivery of the product.	Signal - Text, Digital, Voice	The item that is delivered can be identified by their ID and signaled back upon delivery.
21.2	DPM	DCM	Inform	Route the signal from DE to DCM.	Signal - Text, Digital, Voice	The item that is delivered can be identified by their ID.
21.3	DCM	OM	Inform	Route the signal received from DPM to OM and inform the delivery of the product.		
22.1	MCM/ ICM	ICM/MCM	Inform / Accept	Coordination for taking custody of the assets.		
22.2	ICM/MCM	MCM/ ICM	Accept			
ME now conducts diagnosis and inspection						
23.0	ME	MPM	Inform	It conveys to MPM the additional resource requirements if necessary.		Optional

Continued Table 4.1: Return of MRO to Stock

Step	Speaker	Listener	Performative	Content Description	Attributes/ Media	Descriptions
MPM identifies and requests the additional resources and parts to effect repair if necessary.						
24.0	MPM	MCM	Inform	Send the signal about the additional resource requirements.		Optional
25.1	MCM	ICM	Ask/Accept	Request for the additional resources that are required.		Optional
25.2	ICM	MCM	Accept			
ME then perform the repair and checks for quality.						
26.1	MCM	ICM	Inform	Requirements for returning the item.		
26.2	ICM	IPM	Inform	Ask IPM to reserve and schedule the resources for accepting the repaired item.	NSNs, Quantity, Order ID, Time frame. - Text, Voice	The list and quantity of items and time frame can be sent using text forms.
27.0	ICM	DCM	Inform	Notify DCM about the shipping requirements.		
28.1	DCM/ ICM	ICM/DCM	Inform / Accept	Coordination for pick up and delivery of the repaired item.		
28.2	ICM/DCM	DCM/ ICM	Accept			
28.3	ICM	MCM	Inform	Inform that the item is ready for return.		
28.4	ICM	OM	Inform	Inform that the item is ready for return.		
29.1	IPM	IE	Inform	Generate and direct IE to schedule resources for receiving the returned item.	NSNs, quantity, packing rqmts, Time to receive, Priority - Text, Voice, Digital	The work order that contains the resources to be made ready for receiving can be sent again as an e-form. The priority is a machine generated digital code.
29.2	IE	IPM	Accept			
30.0	DCM	DPM	Inform	Reserve and schedule the resources for pickup and delivery of the repaired item.	Transporting unit ID, Time to pick-up, Location - Text, Voice, Digital	The identified products are listed out and sent.

Continued Table 4.1: Return of MRO to Stock

Step	Speaker	Listener	Performative	Content Description	Attributes/ Media	Descriptions
31.0	DPM	DE	Inform	Generate and direct work order to pick up and deliver the repaired item to IE.	Item ID, Location, Destination location - Text, Voice	The location from where to pick-up the item and product lists are sent using the e-forms.
The Item is picked up and returned to the designated IE/IPM by the distribution execution element.						
32.1	DE	DPM	Inform	Signal about the delivery of the item.	Signal - Text, Digital, Voice	The item that is delivered can be identified by their ID and signaled back upon delivery.
32.2	DPM	DCM	Inform	Route the signal received from DE to DCM.	Signal - Text, Digital, Voice	The item that is delivered can be identified by their ID and signaled back to DCM.
32.3	DCM	OM	Inform	Route the signal received from DPM to OM and confirm delivery.		
33.1	IE	IPM	Inform	Verifies records and reports discrepancies about the item received.	NSN, Description of item quality - Text, Voice, Digital	The condition of the received item is sent as text.
33.2	IPM	ICM	Inform	Routes the information about the received product to ICM.	NSN, Description of item quality - Text, Voice, Digital	The condition of the received item is sent as text.
33.3	ICM	OM	Inform	The information about received item is notified to OM. Receipt.		
34.0	OM	FM	Inform	Liquidate funds if required.	Invoice - Text, Encryption, Digital	The invoice is sent as text with encryption.

The information flow diagrams capture the sequential flow of information across the nodes for each use case. The tables in combination with the information flow diagrams clearly articulate the transactions within each use case. We have identified 17 use cases as shown in Figure 4.1. In Table 4.2 column 2 refers to the corresponding OA tables, column 3 refers to the information flow diagrams and in the last column we specify the page number and the Appendix report where these details can be found.

Table 4.2: Completed Use Cases and Reference

Use Case Names	Tables	Information Flow Diagrams	Reference (Pages in **Appendix 10.5 Interim Report 3** (IR3))
Product Order Fulfillment for a Stocked Item	✓	✓	IR 3 44 – 47
Product Order Fulfillment for a Non-Stocked Item	✓	✓	IR 3 48 – 50
Multiple Source Request	✓	✓	IR 3 51 – 52
Return of Excess Item to Stock	✓	✓	IR 3 53 – 56
Return of MRO to Stock	✓	✓	IR 3 57 – 62
Return of Defective Item to Source	✓	✓	IR 3 63 - 66
Return of Hazardous material for disposal	✓	✓	IR 3 67 – 70
Maintenance at IMA	✓	✓	IR 3 71 – 75
Maintenance at Customer	✓	✓	IR 3 76 – 79
Procurement fulfillment	✓	✓	IR 3 80 – 81
Basic distribution for product order fulfillment	✓	✓	IR 3 82 – 84
Movement of personnel and equipment for services one-way	✓	✓	IR 3 85 – 87
Patient Movement	✓	✓	IR 3 88 – 90
Provide health services at customer site	✓	✓	IR 3 91 – 94
Engineering services using organic resources	✓	✓	IR 3 95 – 98
Customer service - problem relating to a customer order	✓	✓	IR 3 99 – 101
Customer service- customer inquiry	✓	✓	IR 3 102 – 103

Note: ✓ implies the particular use case has been analyzed and documented

[Maintenance at IMA]

-[22]-[26] ME conducts diagnosis & inspection and captures the cause of failure; MPM identifies & requests additional resources & parts to effect repair (if needed)
-[27.1]-[27.3] → ME performs repair and conducts quality control
-[28]-[35] → ME stages repair item for return to customer, and MPM releases repaired item
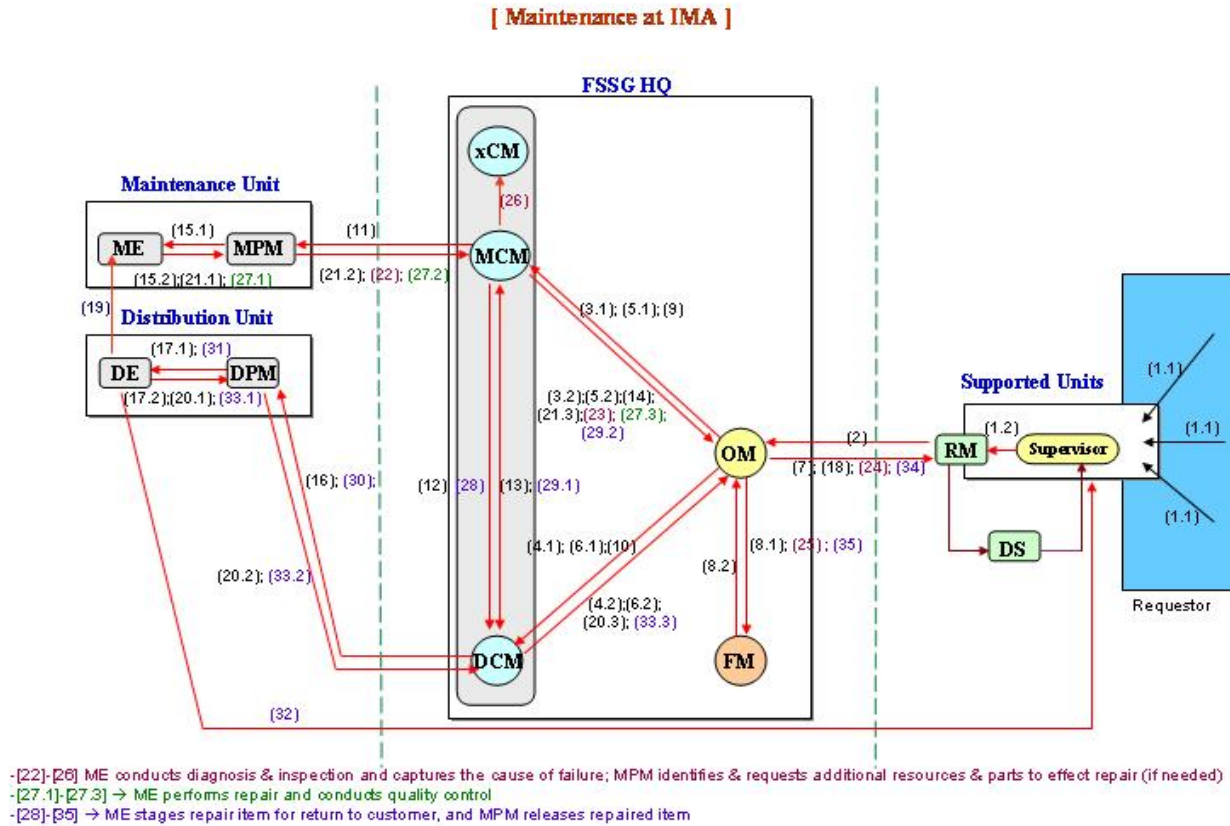
Figure 4.2: Information Flow Diagrams for Maintenance at IMA

The information flow diagram, Figure 4.2, shows that the requests are generated "as occurring" and routed through the related personnel or "supervisor" for authentication to the centralized support group. The centralized support group is a combination of an Order Management System and the management teams (human-in-the-loop). The orders received by the system are parsed and relevant data elements are distributed to the various CM modules (ICM, DCM, etc.). This information is also visible to the management teams based on which relevant decisions can be made and their data decision requirements.

Depending upon the availability of the services/products requested, the CM modules will signal the production management units with the relevant information. The production management units use this information to generate specific work orders, pick-up/delivery orders, etc., as required and transmit them to the execution units under their command. Upon receiving the services/products through the executing units, the supported units signal the order management system about the receipt. The order management system then updates the inventory database and records this event in its historical database. The management teams have near real time information visibility. The order management system maintains a comprehensive database of the

availability of different products/services within its domain, which is continuously updated.

The processes within the OA are specified from an operational perspective but there is a need to determine the underlying technologies that will enable these processes. The use of a particular technology will greatly affect the efficiency and performance of the service support group. In order to determine the relevant wireless technologies and portable devices that are relevant to specific OA processes, we had to first define information and organizational overlay. Defining these subsequently enabled rigorous analysis. Once the nodes within the defined scenario were identified, use of wireless technologies as opposed to a wired infrastructure, for the different segments, was assessed. We have identified information flows between the various OA processes. We have used the formalisms derived from software agents to analyze and tabulate information flows systematically. A detailed review of different interacting nodes mapped to the information helped us identify the wireless technologies that are relevant to specific segments between two nodes. These details within the context of military operations are described in Chapters 5 and 6.

5   Determine Unique Military Considerations

Task 4: Determine unique military considerations
4.1 Identify the unique military considerations that will inhibit or enhance the use of portable/wireless technology (e.g., deployability, environment, integration with current/future Marine Corps IT systems). These considerations will include the availability of domestic and international bandwidth.

5.1   Mapping the OA Processes to USMC Operations

In this chapter we explain the details developed through the information flows and node-to-node connectivity tables in the context of USMC operations. We first identified and mapped specific nodes described within the OA to organizations within the USMC. Based on these mappings we have defined specific scenarios. The scenarios present the context and environment in which the developed future logistics systems will be deployed and used. Such analysis helped us identify the approximate range of communication, the data types that would be sent and other environmental impacts. In order to improve the granularity of the requirements specifications we have divided the communication links into specific segments: supported unit (SU) - RM; RM-OM; OM-PM; PM-E. At the high-level, communication has to be enabled between the supported units, the supporting units and the sea-based logistics support. Based on this analysis we generated the requirements specification for specific segments within the communicating nodes. The first few sections focus on wireless technologies that will help enable efficient communication across the logistics chain; the later sections explore the use of wireless technologies and devices for other functions such as routing for distribution and inventory tracking.

5.2   Identifying System Requirements

Often high-level system architecture descriptions are misinterpreted as lacking in depth. These descriptions tend to be more subjective, broadly explained and impossible to implement. However, we have generated a detailed version of the higher-level abstraction. In order to accomplish this we need a rational and scientific basis. We therefore, analyzed many use cases to develop a clear understanding of the related OA processes and the ensuing information flows. The tables and information flow diagrams helped to compute the following requirements within the context of military applications:

- Connectivity
- Range of communication
- Response time
- Link capacity within the wireless network
- Medium of communication (text, voice, image and digital)

The tables and information flow diagrams in Appendix 10.5, Chapter 5 Interim Report 3 that were developed can also be used for educating the teams that use/develop the wireless architecture. The information flow diagrams generated can be combined to develop a unified view of the transactions that take place between the nodes as shown in Figure 5.1. This will form the foundation for developing the systems architecture view. Each system would be a single node or a cluster of nodes. The capabilities and requirements for a system would be the same as the nodes that it represents. For instance, the request management system would have the capabilities identified for the RM node across all the use cases.
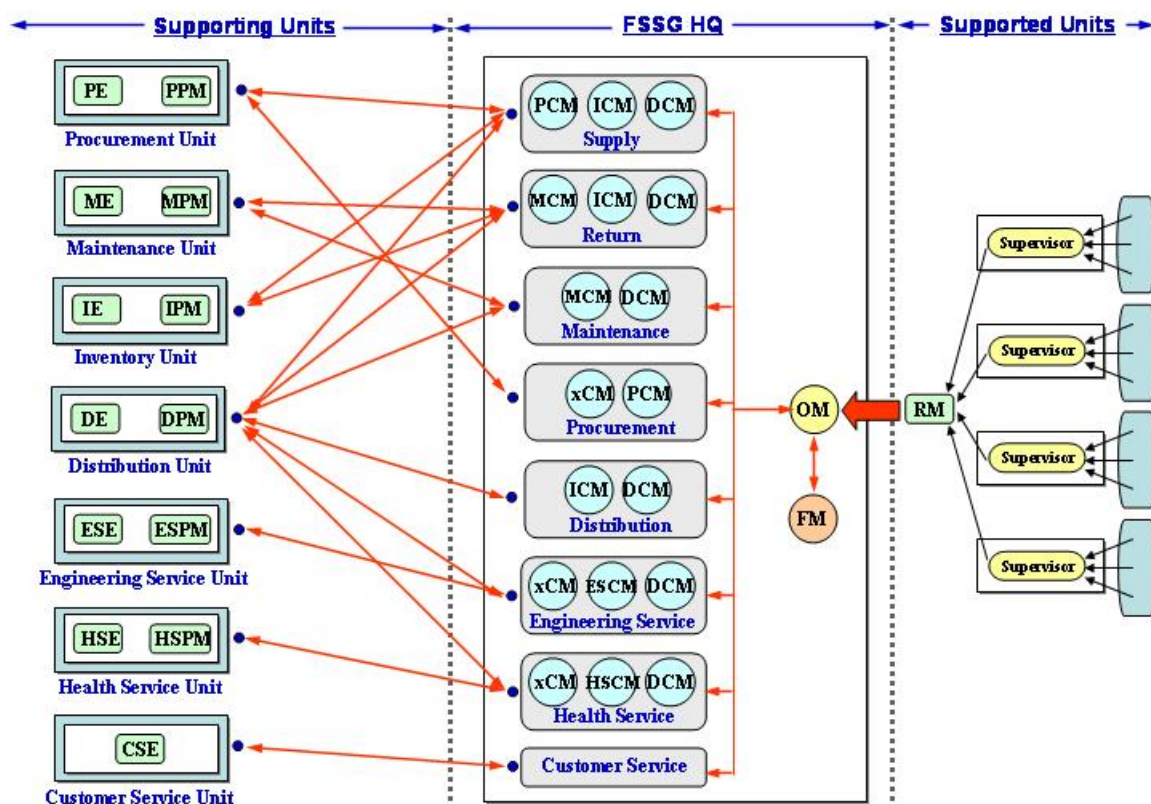
Figure 5.1: Unified View of the Transactions between Various OA Processes

To generate a unified view as shown in Figure 5.1, we have considered requests of various types from the supported units to trigger the OM system. This unified view helped us to identify the common nodes that are triggered as well as their requirements.   By coordinating with the CM module, the OM system supports all planning activities.   The PM and E modules are assumed to be distributed geographically.   Hence, we consider a centralized control and distributed execution.

43
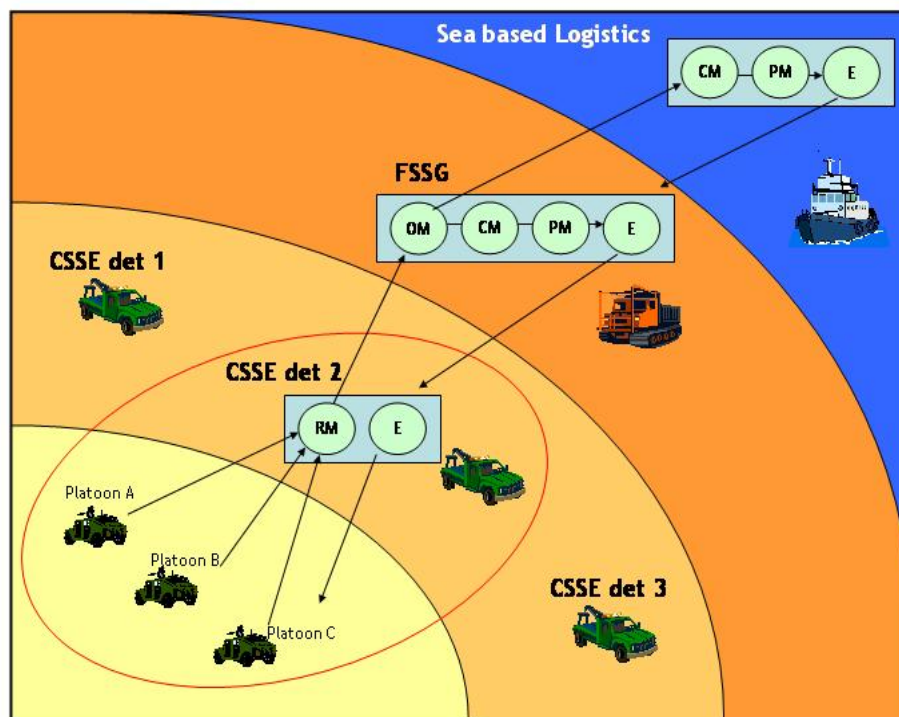
Figure 5.2: OA Processes with Relevance to the USMC Organizations

Figure 5.2 shows the unified view of all the OA processes with relevance to the USMC organizations. Figure 5.2 shows three significant segments within the USMC hierarchy. They are:

- Supported Unit (a group of platoons supported by a CSS Element Detachment (CSSE Det))
- FSSG-Centralized Support Service Group (CSSG)
- Sea based logistics

Supported unit has both the RM process and internally sourcing execution process. FSSG has OM, CM, PM and E. Sea-based logistics is responsible for managing inventory at a large scale and replenishing the requirements at FSSG.

The granularity of Figure 5.2 can be improved by considering a specific instance such as "a request for maintenance". This is shown with its different levels in Figure 5.3. The RM segment is common across all use cases, but differs at the FSSG level as shown. The OM for this instance triggers the maintenance capacity management module and distribution capacity management module. This in turn triggers its relevant production management module and execution module.
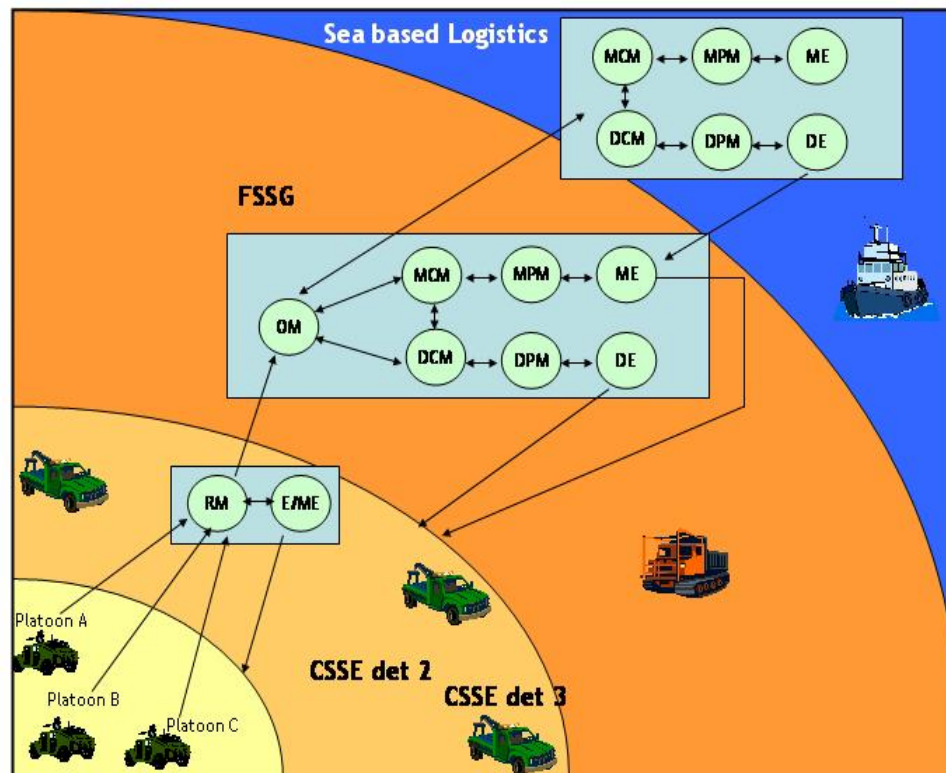
Figure 5.3: Instance for OA Processes between the USMC Organizations

Observations

The analysis of Table 5.1 (OA Table 4.1) shows the required medium of communication for the different OA processes. Obtaining data from the USMC personnel regarding the frequency with which the requests are generated and the physical distribution of the elements in a deployed environment helped to estimate the volume of data exchanged. This will primarily influence the type of wireless communication network that has to be used and also the size of the required infrastructure.

Table 5.1 shows the communication media and the technical requirements for different OA processes. The approximate size of the data transmitted using each of the media is also computed.

Medium Definitions [OA-Compact Disc]

- "Digital" implies that the primary means of transferring information or data is via automated interface (e.g., publish-and-subscribe where transactions are published to a database and other applications subscribe to receive updates from that database; transaction-based is where one application is available to receive transactions from another application as they occur. This does not imply that a human does not ultimately benefit from the information in some form.   For example, the ultimate medium for a digital transaction could be in text form based upon interpretation of an automated system.

- "Voice", "Text" and "Image" imply that there may be direct human-to-human or computer-to-human interaction for the purpose of communicating information directly for human interface.

Table 5.1: Medium Requirements for OA Elements

	E-form / Text	Digital	Voice	Image	Location GPS Information
Request Management	*	*	*		*
Order Management	*		*		*
Production Management	*	*			*
Execution	*			*	*
Capacity Management	*		*		*
Requirements	Data Communications	Encryption / Decryption Module	Telephony Service	High Communication Speed	GPS
Data Size	~0.68 kbps	~ (1.3 * original data) kbps	~ > 50 Kbps	~ 600kb	~ 50b/sec

5.2.1 Data Size Calculations

Text: The text data is assumed to be generated from a handheld PDA with screen size 320 * 240 pixels (for e.g., HP ipaq). This equals 20 lines of text with 33 characters each (660 characters). Thus, the size of text-based message can be assumed to be 0.66 Kbytes.

Encryption: Standard encryption algorithms increase the size of data to 1.3 times original data.

Image: A colored image consisting of 256 colors generated from a 320*240 pixel hand held device would have a size of 600 Kbytes.

Table 5.2 details the various wireless communication technologies and their relevant capabilities such as range, communication speed, etc. Table 5.3 shows the technologies for providing location-based services.

Table 5.2: Wireless Communication Technologies

	Personal-Area Network	Wireless LAN	Wide-Area Network	Satellite Network
Range	Up to 10 meters; Peer-to-peer	50 – 200 m; Campus size	Greater than 5,000 meters; nationwide	Nearly unlimited; Worldwide
Communication Speed	1 Mbps	4 – 11 Mbps	27-153 kbps	2.4 – 400 kbps
Technology	IrDA Bluetooth	802.11x	CDMA2000 1xRTT GSM GPRS	Iridium, LeoOne, NewICO, OrbComm, Skybridge, Spaceway, teledesic
Strength	▪ Low cost	▪ High speed Communication	▪ Wide Communication Range ▪ Relative Low Cost	▪ Wide Communication Range ▪ Security
Limitation	▪ Short Comm-unication range	▪ Security ▪ Relative short communication range	▪ Depend on Base Station ▪ Security	▪ High Cost ▪ Low Communication Speed ▪ In-house Communication

Table 5.3: Location Services

	Cell ID	EOTD, AFLT	GPS	A-GPS (Assist)
Accuracy	100–1000 m (Cell)	75–300 m	15–150 m	1–10 meters
TTFF (Time To First Fix)	< 5 sec	< 5 sec	10–60 sec	< 5 sec
Added Cost	None or very Low	Low	High	High
Application Area	Situation where neither GPS nor EOTD/AFLT	Dense urban, indoor and underground application	High precision needed in urban and rural environment	

5.3 Inventory Tracking - DoD RFID Goals

In October 2003, the U.S. Department of Defense (DoD) announced its Radio Frequency Identification (RFID) Policy. RFID technology greatly improves the management of inventory by providing hands-off processing. The equipment quickly accounts for and identifies massive inventories, enhancing the processing of material transactions. In addition to reducing supply chain management and tracking needs, RFID will enable DoD to improve business functions and facilitate all aspects of the DoD supply chain.   However, the reality of RFID implementations falls short of the theoretical possibilities.

The new policy will require suppliers to put passive RFID tags on the lowest possible piece part/case/pallet packaging by January 2005. Acknowledging the impact on DoD suppliers, the DoD has hosted summits for industry vendors and its suppliers; this report includes information from the most recent April 2004 RFID Summit. The RFID policy and implementation strategy will be finalized by June 2004. The RFID policy and the corresponding RFID tagging/labeling of DoD materiel are applicable to all items except bulk commodities such as sand, gravel or liquids [1]. The DoD goal is total asset visibility, with a desire to link the "foxhole to the supplier factory floor" for critical items [2].

Mr. Ed Coyle, Chief, DoD Logistics AIT Office, DLA, stressed the importance of the warfighter in its planning for possible RFID implementations. In the readiness, sustainment, closure and reset cycle of U.S. force deployments, Coyle noted the

new challenges of rapidly moving a force on a dynamic battlefield, and the need for better information on in-transit assets and underlying demands for more effective management of inventory. This requires better real-time information.

The DoD RFID Summits for Industry are a way for the military to share its goals with its suppliers and with RFID software and hardware vendors.   Some key issues surrounding RFID implementation include

- Identification of items to be tagged – current DoD thinking is that all items in excess of $5,000 and/or which have a DoD unique identifier will need to be RFID enabled.
- Identification of the level of tracking desired – in transit visibility must be rationalized at the individual item, case, pallet and container level.
- Use of DoD Unique Identifier (UID) or the Electronic Product Code (EPC) identifier – currently the UID number is longer than that which can be accommodated in the EPC identifier. DoD and the EPCglobal, the international ID agency, are discussing ways to accommodate this discrepancy.
- Linkage of UID or EPC to inventory systems through AIS systems – tracking can only be facilitated if the ID numbers are transmitted to the current inventory support systems.
- Linking UID or EPC to Advance Shipping Notices (ASN) to improve knowledge of incoming inventories (and to increase efficiency of payments to suppliers).
- Preferred use of passive RFID tags to track inventory and asset visibility. Current DoD use of active tags such as those produced by SAVI for container tracking is not envisioned at the item level or case-level. There are some opportunities for active tags at the pallet level, but this is not the current DoD preferred option.
- Use of read-only or read/write tags – the complexity and longevity of tags must be evaluated to determine the best solution on an item-level or larger basis.
- Worldwide RFID enabled visibility and the Status of Forces Agreements that require reporting.

Presently, the DoD estimates that there are over 4.5 million stock units of volume needing to be tracked. The emphasis will be on enterprise integration and expanded end-to-end policies. Using RFID technology, the military hopes to achieve reliable delivery, weapons systems support, performance based logistics, and information about available weapons systems. The military hopes to design out logistics complexity and to reduce the cost associated with identification, authentication and tracking. The hope is to also reduce the current logistics footprint. In return for supplier cooperation, and related to the e-government initiative, suppliers will benefit through rapid payments on tagged items received and transferred to inventory via RFID technologies.

DoD officials also see a benefit using RFID technologies to increase interoperability between international forces. Using common codes (anticipated being a blended version of UID and EPCglobal codes), RFID technology should be able to help rationalize inventories between forces deployed to common regions.   This will require standardization across military platforms, and commonality across international forces, a longer-term goal.

6   Determine Feasible Solutions

Task 5: Determine feasible solutions
5.1 Given the results of Tasks 2-4, recommend feasible portable/wireless solutions and architecture for those processes mutually agreed to between Penn State and the Sponsor. Solutions are further limited to no lower than SCOR Model Level 4 detail.

6.1   Feasible Solutions- Overview

The MEF work environment is dynamic, high-risk, and deadly.   Reliable communication of information is vital.   MEFs, reinforced by maritime pre-positioned assets, allow the United States to protect its worldwide interests, reassure allies, and fortify other elements of national power.

The research in this section was done in near real time, while studying official USMC unclassified printed material from the Operation Iraqi Freedom (OIF). Although SU is not a formal part of the USMC OA, the SU link between SU and RM is included only to establish a seamless communication link between the SU and OA principle nodes.

Unclassified logistics information from the war in Iraq was used to help envision the wireless communication needs of the USMC war fighter and implementation of the OA. The information was provided by the sponsor via personal interviews with USMC logistics supply chain officers that were involved either directly or indirectly with detailed OA-nodes being used in the Iraq war or with unclassified information pertaining to logistic supply nodes used during the war in Iraq.

Also, although this section depicts an implementation of Combat Service Support Company (CSSC) and Combat Service Support Battalion (CSSB) used currently in the Iraq war; it should be mentioned that these nodes may not necessarily be formally envisioned in the final USMC OA implementation, but the same wireless CSSC and CSSB nodes being depicted in this section can be easily folded into the "final" OA envisioned for the USMC.

This section begins with a brief overview of the USMC supply chain nodes with a focus on the expeditionary logistics supply chain scenario depicted in Figure 6.1. For illustrative purposes, supply chain nodes: RM, CSSC, CSSB, FSSG, FM, CM, PM, E, ICM, DCM, MCM and MLC are depicted, including a link to the SU.

It should be noted that the approximate, average communication physical data link distance is listed *in miles* between nodes. Also, it should be noted that communication obstacles, such as unique terrain elevation masking or other related communication link physical obstacles (such as buildings, towers, trees, etc.) were not included, but can be researched in a later study for specific USMC communication-link system requirement needs.

Lastly, in subsequent sections, feasible technical solutions for possible enabling commercial wireless technology, between different nodes of varying physical distances, are discussed.

As a rule of thumb it is also important to note that when a user is mobile, that is, moving with speed and with vehicle dynamics, the wireless communication links may be degraded, which leads to broken communication, lower bandwidth capability and slower data link speeds. In other words, to increase reliable communication, a stationary, non-moving (zero velocity) communication user, located outdoors with a clear line of sight between the transmit antenna and receiving antenna, is likely to be not only optimal, but significantly important to ensure reliable communications between all nodes.

Please keep in mind that although there are numerous choices of wireless communication technology, not all wireless technologies will work reliably in the USMC environment. In other words, there is no single perfect wireless technology that may work for every USMC battlefield scenario. An integrated (hybrid) system of wireless technologies will likely be needed to meet all USMC OA requirements.

For example, a basic premise of a USMC HMMWV using a low earth orbit (LEO) satellite system requires that the user be outdoors and not masked by excessive terrain or other obstacles. If the same LEO satellite system were to be used inside a building with four walls and a ceiling, it is very unlikely that the LEO satellite system would work at all. Instead an indoor wireless technology would be needed in addition to the outdoor satellite communication system. The information provided in this chapter attempts to match wireless technology to each USMC intended environment, respectively.

6.1.1 MEF Environment

This section discusses the MEF battlefield environment as shown in Figure 6.1. Although most of the information is based on the observations, statistics and battlefield setups of the Iraq war, OIF, similar ground-based MEF environments can be assumed for the general modeling of any MEF environment. Again, Figure 6.1 presents the common setup of various nodes, and wireless communication distances between nodes (in units of miles) of the OA, in the context of an actual MEF.
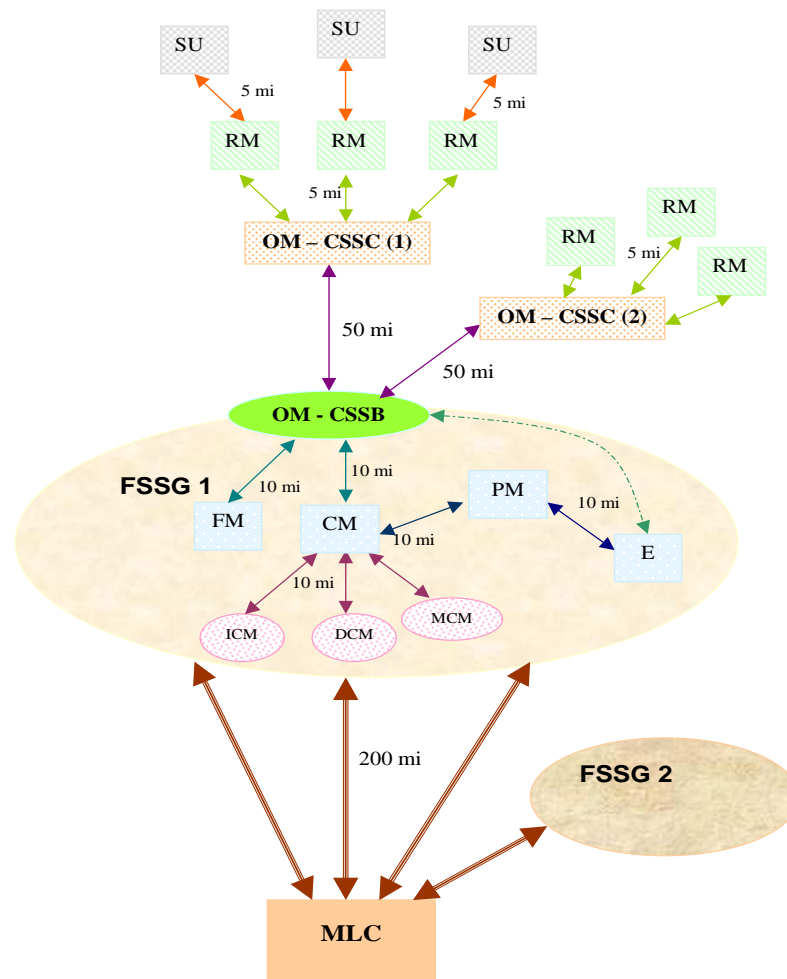
Figure 6.1: Expeditionary Logistics Supply Chain Scenario

6.1.2 Marine Logistics Command (MLC)

Marine Logistics Command (MLC) is the first node in the USMC logistics chain. This node is the primary support node for all kinds of assets, materials, ammunitions, batteries, food supply and in expected to have the supplies stocked sufficiently for supporting the Marine Corps logistics requirement in the actual battle field MEF. During the Iraq war, it was assumed that the MLC was located as a permanent base in Kuwait. The MLC interfaces with FSSGs (CSSBs) for the replenishment of supplies/orders. The expected distance between MLC and FSSG is between 100 and 200 miles. In this study, the distance for wireless communication was not expected to go beyond a maximum distance of 200 miles.

6.1.3 FSSG

The FSSG is the next entity in the USMC logistics chain. It accommodates a number of functional nodes of the OA process. In a battlefield, it is expected to be spread over an area of 10-20 square miles. The maximum area for wireless communication is not expected to exceed 20 square miles. For the discussed area and shape, the maximum distance between the furthest located nodes within the FSSG is normally less than 10 miles. Also, it was noted that FSSG moves in relation to the movement of the SU and CSSC. In other words, the FSSG infrastructure, as shown in Figure 6.2, is mobile, extensive, and its physical geographic location can change depending on the geographical dynamics of the SU and CSSC.

Figure 6.2: Vehicles are Loaded with Ammo and MREs, 1st FSSG Forward Headquarters, IMEF, Iraq

6.1.4 CSSB and CSSC

In MEF setups, the OM functional node described in the OA is actually composed of two parts. These are OM-CSSB and OM-CSSC. OM-CSSB is located within an FSSG. The OM-CSSB and OM-CSSC field scenarios are included in the study.

Figure 6.3: USMC CSSB-18, Retrieving an Amphibious Armored Vehicle, Somewhere in Iraq

Fundamentally, OM-CSSB supports a complete regiment, where a regiment could have a number of OM-CSSC(s) performing actions like those shown in Figures 6.3 and 6.4, or in other words, battalions. Within FSSG, OM-CSSB interfaces with various other OA nodes for the follow-up and delivery of requested orders. The maximum communication distance used in this study between OM-CSSB and OM-CSSC nodes is 50 miles.

Figure 6.4: CSSC-113, Hauling a Bucket-Load of Gravel through a Village near Fallujah, Iraq

Moving further down in the hierarchy in Figure 6.1, each RM is identified with a battalion. It is the authors' understanding that one OM-CSSC supports a number of such battalions (RMs). On the other side of the OA node, RMs communicate with SUs (also known as companies). Note that each RM is envisioned to support a maximum of four SUs. In essence, each RM is placed between OM-

CSSC and SU with a maximum communication distance of 5 miles from both OM-CSSC and SU.   Each SU is expected to have between 200 and 300 personnel. An approximate and general distribution of these personnel is:

- 3 platoons per company
- 3 squads per platoon
- 3 fire teams per squad
- 3 personnel per fire team

Figure 6.5: Damaged Vehicle

Figure 6.5 provides an RM-SU parts request example. Heavy equipment operations platoon with damaged humvee after anti-tank mine blast, near Fallujah, Iraq

It is the authors' understanding that personnel within each SU are posted in relatively close proximity and that the same personnel place their respective supply request(s) to the SU-supervisor in person, or over analog 2-way UHF/VHF radio transceivers. Figure 6.5 typifies the CSSC to SU support.

Estimation pertaining to the number of logistics supply requests/orders
Note: These figures are based on the inputs collected from the Iraq war during a 1-month (March-April 2003) data analysis only. For any given USMC real-world implementation of order requests using wireless communication, it would be necessary to ensure that channel availability or channel capacity could manage the average number of requests, including surges in logistics supply requests. To ensure that channel capacity is never exceeded on any given day, implementation of smart-request procedures, in essence spreading out requests in a more uniform manner over time, would be required.

Garrison: 30,000 requests per month for stocked items.

Battlefield: As per the data collected during the Iraq war (OIF), a total of 120,000 requests were made in 1-month for 160 accounts. These 120,000 requests represent the total number of requests recorded for the entire MEF. It does not include aviation ammunition, or requests that were handled off-line (via radio/phone request). These still represent the majority of requests that were generated during the ground campaign. Of this total, 9,000 orders were for stocked non-air ammunition.

6.1.5 Number of Wireless Accounts

Based on reports from a USMC logistics officer, logistics supply data from the Iraq war showed that each SU, CSSC and CSSB request/order is usually tracked by a separate supply tracking account. Any unit authorized to place a request has an account. Usually, the orders are placed by SUs, but the authors were informed that, on occasion, an order could be placed by a CSSE (CSSC or CSSB) for the replenishment of local stocks. It is also possible to have multiple accounts for any of these units in specific circumstances. The statistics mentioned above were collected for 160 such accounts, taken together.

From the information the authors gathered, the geographic topology in the Iraq war had 11 CSSE (3 CSSB and 8 CSSC) with 25 accounts, and the rest of the 135 accounts were with SUs (sometimes more than one with a single SU). It should be noted that distribution of these accounts with different CSSBs was not uniform; however, the maximum number of accounts with one CSSB was approximately 24.

Resources/services identified in MC logistics chain
For this study the types of services considered as requested in the field are Supplies, Maintenance, Transportation, General Engineering and Health Services. Supplies included oil and lubrications, petroleum, batteries, ammunition, and field fortification items.

6.2 Feasible Modes of Communications Between Various Nodes

Intra-SU communications: SU is a company sized area with platoons, fire squad etc., moving together in a maximum diameter of 1 mile. Note that an SU usually has a supervisor, who is in charge of collecting requests for that SU. Personnel in SU are always mobile and their distances with the SU supervisor vary with their movement; however, they remain generally within a range of 1 mile. Personnel within an SU, place verbal and written requests to an SU

supervisor. In the latter case, the communication request is either made in person or by use of 2-way voice, analog, or digital radios.

SU ↔ RM: Similar to the SU, RM is also a mobile unit. RM moves with SU in the direction of SUs movement. Clearly, the distance between the RM and SUs will vary. However, the maximum distance between these nodes for this study was no more than 5 miles at all times.

A number of infrastructural scenarios are possible to provide communication on this link. Possible field scenarios and the technology that can be used depend on whether a land-based infrastructure such as cellular or fixed-tower communications exist or have been deployed and set up in the field.

a. *No land-based infrastructure support, no base stations:* Typically, it should be possible to support the communications between SUs and RM using satellites for all distances beyond 100 meters in the absence of infrastructure. Among satellite systems, low earth orbit LEO satellite systems have significant advantages over medium earth orbit (MEO) and geo-synchronous earth orbit (GEO) satellite systems in terms of needed electrical power, antenna size, and antenna orientation (readjustments required for uninterrupted connectivity). Since the distance between the terminal and satellite is considerably less in LEO systems, terminals spend less power for the same amount of data transmission and require a much smaller antenna (today, approximately the size of a hockey puck).   As a back up to the LEO satellite communication, a digital packet data overlay on the current voice radio frequencies could be used. The latter would require an upgrade to the current VHF/UHF radio, but not require an additional radio.

Below 100 meters, communications could be facilitated by equipping RMs with 802.11g variant with multiple access points or possibly using near-future long-range (30 mile claimed) commercial 802.16 systems with SUs that could be similarly equipped. These short-range 802.11g communications does not require any conventional infrastructure. Bluetooth and Ultra Wide Band (UWB) Radio can also facilitate communications below 25 meters. Note here that voice communications using 802.xx can be supported with voice-operated Internet protocols (VoIP) on top of the TCP/IP stack.

Because the mission of the USMC involves expeditionary work in remote areas of the world, a reliable means of wireless communication would mostly fall back on satellite connections. Note that LEO satellite systems such as Orbcomm, GlobalStar and Iridium could be considered reliable for low-bandwidth data communication. They support secure encryption of data

transmission over the air with commercially available encryption software of all data being implemented prior to data transmission and post-processed on the receiver end.

b. *Infrastructure with base stations installed:* This type of infrastructure is also described in Figure 1.2 of Appendix 10.5, Interim Report 3. Here, if the SUs (or mainly SUs supervisor) and RM can be covered by a single or a network of base stations, then communication between SU and RM can be facilitated using this deployed infrastructure. Once again, connectivity can fall back on 802.11g, Bluetooth and UWB radio in case of short-range communications. In this case, the network of base stations must have the coverage to support the mobility of SU and RM. Otherwise, communications between these two units will have to fall back to a small, simple antenna footprint using LEO satellite communications.

Considering the mobile nature of the SUs and RM, equipping these units with multimode handsets may appear to be a good solution. This will result in efficient utilization of the bandwidth and overall lower cost of the solution. An appropriate technology or system could be selected for communications between RM and SUs, depending upon the available infrastructure and coverage of the technologies. Present terminal designs allow automatic selection of technology in a defined order i.e., selection of latching up with cellular network in case coverage is available with priority, otherwise a fall back on satellite communications, whose coverage is ubiquitous. To help power the handsets, the possibility of using alternate fuel-cell battery technology may be beneficial by being longer lasting.

SUs are also expected to provide the location information along with the order for accurate and timely delivery of the requested service or item. For that purpose, SUs must integrate the use of GPS for accurate estimation of location and precise time of day. The geo-location and time of day information provided by a low-cost commercially available C/A code GPS receiver should be adequate to update the necessary delivery information to RM and other nodes in the logistics chain (as well as for the delivery of a previously requested order). *GPS assisted satellite, cellular and PDA terminals are available in the market today.*

RM ↔ OM-CSSC: As discussed above, the maximum distance between these two nodes is approximately 5 miles. There are a number of options for connectivity between these two nodes:

a. Satellite-based communications, with each RM supported on a separate connection. Again an LEO satellite system is a preferred choice. As a backup,

a stationary, quick-set-up, line-of-sight satellite system for data transmission (similar to what commercial businesses use to send/receive credit card transactions, used at many gasoline fuel pump stations and other low-data needs) could be utilized. Again, information would be tagged with GPS geolocation information and GPS time of day.

b. If all RMs or a subset of RMs are closely located and can be served by a network of base stations, then these RMs can communicate with this network, each over a separate connection. One of the base stations in the network can act as relay node by transmitting the requests (or voice and data traffic) over a single satellite connection with OM-CSSC. Here any RM can also act as a relay node for the routing of other RM requests by establishing a satellite connection with OM-CSSC. Note that this option has the advantage of equipping only a single base station or RM with satellite communication capabilities, resulting in cost savings.

c. If a network of base stations can cover both RM and OM-CSSC, then there is likely no need of satellite connectivity; however, satellite-based communication could be used as the backup.

Again, RM is also expected to provide the geolocation information to the OM-CSSC. It can both use the location information provided by the SUs, as they are the primary initiator of the request, or RM itself can generate the information using an equipped GPS terminal and append it to the original request. It should be noted that LEO satellite systems such as GlobalStar could also provide a coarse geolocation of the user that may be helpful as a redundant positioning system to GPS.

OM-CSSC ↔ OM-CSSB: The maximum distance of this link is 50 miles. There are generally two modes of connectivity:

a. LEO satellite communications, with each OM-CSSC having a separate connection with OM-CSSB. As a backup, a stationary, quick-set-up, line-of-sight satellite system for data transmission could be reliably utilized. This commercial type of system and antenna size is similar in size to that used in the "Dish" satellite network.

b. A network of base stations provided the network covers both OM-CSSB and OM-CSSCs. If a number of CSSCs are closely placed and capable of exchanging information among each other securely without satellite connection, then one of these CSSC can possibly assume the role of a relay for communication with CSSB using a single satellite connection. In case of

mobility, the network must cover OM-CSSB and OM-CSSCs at all times to enable connectivity; otherwise support for back-up connectivity using satellite could be used.

In various cases discussed above for the mobile setups of SU, RM, OM-CSSC and OM-CSSB in expeditionary environments, it is difficult to develop infrastructure of base stations and then reinstall as they move. In case of garrison, it may be possible to deploy these base stations, but in expeditionary environments this is clearly an expensive and time-consuming option to set up and tear down a land based communication infrastructure. Again, because of the expeditionary nature of the USMC work, communications will likely need to rely on satellite systems.

OM-CSSB ↔ CM, CM ↔ CM-sub-modules, CM ↔ PM, PM ↔ PM-sub-modules:
The maximum distance between various nodes of FSSG is expected to be within 10 miles. Conceivably it should be possible to connect these nodes over wires, as the area covered by the FSSG is relatively private and secure, and the relative position of the various nodes and sub-nodes more or less remain fixed. However, given the fact that FSSGs move with the movement of SUs, it may not be feasible to support FSSGs on wired infrastructure alone.

A number of options could be considered for wirelessly connecting nodes in this secure area.

a. If the distance is below 100 meters and the user is stationary, 802.11g is the choice. If the distance is below 10 meters, Bluetooth can also be used. UWB radio is another candidate for ranges below 20-25 meters. It will be possible to store the request temporarily in 802.11g or Bluetooth terminal if the network of 802.11g access points or Bluetooth's piconet/scatter-net, respectively, does not cover the entire FSSG. In such cases, these terminals may either alert the user once they detect the network for the manual sending of the stored request, or these terminals may automatically place the request.

b. For distances above 100 meters, connectivity can be supported using cellular or LEO satellite communications only. 802.16 is now being developed for distances up to 30 miles, but it is unclear at this time how well this technology will work indoors and outdoors. Clearly, as mentioned previously, satellite communications is a solution that can be used in the absence of any infrastructure. However, it is generally a more expensive solution in regard to airtime costs. Here it should be kept in mind that the number of transactions

between these nodes for a single order is very high in comparison to transactions over RM ↔ SU or RM ↔ OM-CSSC for the same single order.

c. Another option is to support communications using inexpensive voice radios connected with a centralized stationary microwave radio station over a digital data backbone. Currently available voice radios do support alphanumeric text messaging and this feature could be used additionally with voice support inherent with these radios. In the future, this limited capability of alphanumeric text will mostly be enhanced to support higher data rates. Stationarity of microwave stations could pose a problem in the case of a mobile FSSG. Mobile microwave radio stations might be able to provide backup help.

d. Supporting communications by building a fixed cellular network with a sufficient number of base stations is another solution, but again it's understood that the FSSG moves with the movement of SUs. Obviously, it may not be realistic to frequently install, uninstall and re-install the base stations to support the same communications with the movement of an FSSG. A mobile base station (BTS) is a new concept. Such base stations can be installed on moving vehicles. If the relative positions of the various nodes within the FSSG remain the same, then these vehicles can be moved in sync with these nodes/stores/assets/vehicles and communications within the FSSG can be supported without any additional cost. It will be possible to support communications even during the movement without any changes in configuration, reassignments of frequencies and with the same network and end-user equipments. This would have to be field tested to verify utility.

Here, even if the coordinates of the various nodes are changing somewhat or on a large scale, for example, due to varying terrain conditions or susceptibility to enemy attacks, numerous network planning software options are available that can quickly design a new network once the software is provided with new coordinates of the nodes and facilities that are required to be covered.

Network planning software usually produces a number of BTS topology solution sets for network coverage. A feasible set, ignoring unacceptable sets due to rough terrain, etc., can be chosen, and mobile BTS can be placed accordingly. Again, it will be possible to adjust the positioning of these mobile BTS without any major changes in configuration data. At times, power adjustments may have to be done, but network-planning software provides those details, too, and it will be possible to put these configuration changes into service in an automated way.

Nodes within the FSSG may have to be equipped with GPS transceivers for ascertaining their coordinates and data time-tags to assist the network planning software in designing and redesigning the network with movement.

e. Mobile IP is a new platform emerging for supporting communications in IP-based mobile terminals in the IP network. It can also be configured for intra-node communication within the FSSG.

In Mobile IP, a network is composed of Home Agent (HA), Foreign Agents (FA), Fixed Hosts (FH) and Mobile Nodes (MN). Conceptually, MNs register with a HA and are assigned a static and unique IP address. This address is allocated from a pool of addresses available with the registered HA. When an MN moves into an area served by an FA, they are assigned a Care-of-Address (COA) that belongs to FA. MN informs HA about COA for the delivery of their data packets during mobility.

Communication is always between MN and FH, and FH always sends the data packet destined to MN's static IP address. Due to this, data packets destined for MN always arrive at the HA gateway. HA delivers the data packet reliably to the MN locally, if the MN is still being served by the HA, or otherwise it is encapsulated in another IP packet with the COA of the serving FA as the destination address and it is tunneled to the FA. The FA de-capsulate the packet and delivers it to the MN registered with it. Mobile IP requires that all nodes support the TCP/IP stack for connectivity.

PM ↔ E, CM ↔ E:
When the relevant CM and PM have been identified, the Executing units (E) are designated with the responsibility of delivering the same to the requestor. As per the OA architecture, different sub-units of E are designated for different types of service. Instinctively, it is expected that a Maintenance E unit (ME) will be stationed close to a Maintenance PM (MPM); a Distribution E unit (DE) will be stationed close to Distribution PM (DPM), and so on. Once again, the communication between the PM and E can be supported using 802.11g or cellular network, bearing in mind the distance between them.

Mobile IP is a strong candidate for this connectivity, since E units are usually expected to be mobile. Supporting connectivity using Mobile IP with their movement within FSSG can result in a very inexpensive solution.

OM-CSSB ↔ E:
This communication is identified to assist the Executing units with routing information for the delivery of the services to the ultimate end user. The distance

may vary from 10 miles within the FSSG to 60-70 miles at the time of delivery. In battlefield situations, E units may have to be assisted with alternate routes to avoid enemy challenge. Essentially, it is expected that these Executing units will update OM-CSSB with their location information frequently during transit. E units must be equipped with GPS receivers in order to carry out this task. It is also suggested that the operators of these vehicles be provided with accurate GIS-equipped moving street-atlas maps in the vehicles. These maps would allow the driver to see not only designated routes, but also be provided with wireless information pertaining to delivery and pick-up information, friendly forces and other needs for the safe and secure transportation of supplies. The knowledge of location information of the E unit also assists in providing RM/SU with real-time information about the delivery of the service requested.

Since these Executing units are expected to have connectivity with OM-CSSB at all times and considering that these E units are expected to be moving in the field, they must be equipped with the best LEO/MEO/GEO satellite communications capabilities. In addition, E units should have the capability to switch between communication links on the fly as needed to maintain a reliable communication link at all times. Communications with the FSSG can also be supported using cellular communications and mobile IP infrastructure. For added redundancy, wireless digital communication using VHF/UHF data overlay on current voice frequencies is suggested. All information could be encrypted by pre- and post-processing the data prior to sending and after receiving.

The delivery operators would use hand-held notepads capable of wireless Bluetooth and 802.11g technologies. Additional logistics supply chain needs would be to utilize a portable device that scans 1-D and 2-D bar codes and reads and kills RFID tags. The information from this hand-held device would need to be integrated with the vehicle's LEO/MEO/GEO satellite communications and GPS wireless infrastructure. If predicted 802.16 wireless Internet communications is feasible, then this technology could also be used as a redundant system for added reliability.

FSSG ↔ *MLC:* This interface can be supported on a single satellite connection, considering the nature of range of 200-mile distances between these two units. Supporting this connectivity by developing an infrastructure of base stations is not likely to be an economical solution, especially if the infrastructure is temporary.

In the USMC logistics chain, assets/stocked items can be tracked across all the nodes using bar codes and passive and active RFID tags. Bar code is the current and proven mechanism for tracking commodities of all types. RFID is emerging fast, as it has the tendency to collect identification and other useful

information without manual intervention. As mentioned, RFID tags are of two types: passive and active. Active tags do tend to provide information from a longer distance in comparison to passive tags, as active tags have their own battery backup and they don't rely on energy captured from the reader for communications. Active tags can be attached to expensive, inflammable assets such as explosives, etc., for pallet and crate-level tracking of these items. These tags can be tracked when trucks carrying pallets arrive at the warehouse for delivery by fixed readers located at the entrance of the facility and information is updated automatically in the related databases. This way, assets/items can be tracked all along the transit from MLC to PMs in FSSG and during the delivery of the order to the SU and CSSCs. Passive tags will likely be initially implemented to track and trace back pallets of goods, followed by using passive tags to track boxes of goods and eventually individual end-items. The adequate and reliable use of unique identification (UID) will need to be implemented, as well as reliable processes to create, re-use, kill and dispose of RFID tags.

In the future, these tags are expected to store more information than just identifications. It is also expected that various nodes in transit may write additional information such as date of arrival, location coordinates of delivery, or date of expiry in the case of perishable commodities on these tags. Enhanced RFID systems with next-generation high-memory read and write tags will have to be used for this level of tracking. In the foreseeable future, each and every small item may have to be tagged instead of present implementations where only pallet-level tracking is done using RFID tags. Use of RFID could provide a cheap and automated mechanism of tracking, stock-keeping and timely delivery of assets in the MEF.

Table 6.1 summarizes the modes of communication on the various links discussed previously. Most of the information for attributes, media, and descriptions has been picked from use cases described in Appendix 10.5 Interim Report 3 (Appendix 9.5). In Section 4.2 of this report, one representative table is shown. Some additional information has been added in the appropriate cells in the backdrop of information gained about the actual MEF environments. In the "possible solutions" column, potential options have been suggested though it may not be feasible to use cellular communications in mobile MEF setups.

Table 6.1: Summary of Modes of Communication

Step	Speaker	Listener	Attributes	Media	Descriptions	Possible Solutions (Range 'm' == 'meters'; 'M' == 'Miles')
1	Requestor within SU	SU-Supervisor	Unit ID, Quantity Expected time for replenishment	Voice (Digital or Analog)	Placed in person or over 2-way radios.	× 2 way portable radio, analog or digital voice VHF/UHF radios × Digital data overlay voice radios
2	SU-supervisor	RM	Unit Identification, NSNs, Quantity, Location information, Expected time for replenishment. Encrypted	Text Digital-Voice	▲ The request could be sent as an e-form. ▲ The location and time-tag information is identified by the GPS enabled device and sent along with the form. ▲ The voice acts as a backup for human – human interface. ▲ Password encrypted	× No terrestrial infrastructure (Range>100m): LEO Satellite communications × No terrestrial infrastructure (Range<100m): 802.11g, Bluetooth, UWB × Possible future backup: 802.16 (<30 mi) × With terrestrial infrastructure: Cellular (GSM/GPRS/CDMA2000/UMTS/TDS-CDMA); Satellite communications can be used as back-up GPS enabled Satellite phones, Cellular phones; PDA and pocket PC terminals are available. These terminals support encryption of digital data and voice.
	RM	SU-supervisor	Unit Identification, NSNs	Text, SMS Digital-Voice	▲ Delivery status update based on Unit identification, NSN ▲ Request Location information update for delivery ▲ *Password encrypted*	× No terrestrial infrastructure (Range>100m): LEO Satellite communications × No terrestrial infrastructure (Range<100m): 802.11g, Bluetooth, UWB × Possible future backup: 802.16 (<30 mi) × With terrestrial infrastructure: Cellular (GSM/GPRS/CDMA2000/UMTS/TDS-CDMA); Satellite communications can be used as back up.
3	RM	OM-CSSC	Unit Identification, NSNs Quantity, Location information, Expected time for replenishment. Secure signature - Encryption	Text, Digital-Voice	▲ In addition to the request, forms a request ID + authentication is automatically generated by the system, which would be some digital information. ▲ RM may add its location information.	× No terrestrial infrastructure (Range>100m): LEO Satellite communications × No terrestrial infrastructure (Range<100m): 802.11g, Bluetooth, UWB × Possible future backup: 802.16 (<30 mi) × With terrestrial infrastructure: Cellular (GSM/GPRS/CDMA2000/UMTS/TDS-CDMA); Satellite communications can be used as back up. GPS enabled Satellite phones, Cellular phones; PDA and pocket PC terminals are available.
	OM-CSSC	RM	Request ID confirmation	Text, SMS, Voice	▲ Confirmation of the request by sending the request ID back and forth with the customer. ▲ Request Location information update for delivery	× No terrestrial infrastructure (Range>100m): LEO Satellite communications × No terrestrial infrastructure (Range<100m): 802.11g, Bluetooth, UWB × Possible future backup: 802.16 (<30 mi) × With terrestrial infrastructure: Cellular (GSM/GPRS/CDMA2000/UMTS/TDS-CDMA); Satellite communications can be used as back up.
4	OM-CSSC	OM-CSSB	Unit Identification, NSNs Quantity, Location information, Expected time for replenishment. Secure signature - Encryption	Text, Digital	▲ OM-CSSC may add another ID identifying RM, from where the request is coming. ▲ OM-CSSC may add its location information.	× No terrestrial infrastructure: LEO/GEO Satellite communications × With terrestrial infrastructure: Cellular (GSM/GPRS/CDMA); Satellite communications can be used as back up. Also, possible future backup: 802.16 (<30 mi)
	OM-CSSB	OM-CSSC	Request ID confirmation	Text, SMS, Voice	▲ Confirmation of the request can be achieved by sending the request ID back and forth with the customer. ▲ Location information update	× No terrestrial infrastructure: LEO/GEO Satellite communications × With terrestrial infrastructure: Cellular (GSM/GPRS/CDMA); Satellite communications can be used as back up. Also, possible future backup: 802.16 (<30 mi)
5	OM-CSSB	FM	List of materials, unit cost quantity, Total cost, customer ID, Availability, Encryption	Text	▲ The total cost for procurement is presented as an e-form. It is encrypted and sent for confirmation of availability of funds.	▲ Voice radio connected to Microwave radio stations supported over digital data backbone ▲ Cellular infrastructure supported on mobile BTS or fixed BTS: GSM/GPRS/CDMA/UMTS/TDS-CDMA ▲ No terrestrial infrastructure (Range>100m): LEO Satellite communications ▲ No terrestrial infrastructure (Range<100m): 802.11g, Bluetooth, UWB; possible future backup: 802.16 (<30 mi) ▲ Mobile IP with IP terminals

Continued Table 6.1: Summary of Modes of Communication

	FM	OM-CSSB	Invoice, Encryption	Text	⋏ An invoice for financial claims is sent using e-forms and encryption techniques.	⋏ Voice radio connected to Microwave radio stations supported over digital data backbone ⋏ Cellular infrastructure supported on mobile BTS or fixed BTS: GSM/GPRS/UMTS/CDMA/TDS-CDMA ⋏ No terrestrial infrastructure (Range>100m): LEO Satellite communications ⋏ No terrestrial infrastructure (Range<100m): 802.11g, Bluetooth, UWB; Possible future backup: 802.16 (<30 mi) ⋏ Mobile IP with IP terminals
6	OM-CSSB	CM	Ask /Accept	Text	⋏ Ask the availability of the product and ICM agent either accepts or rejects.	⋏ Voice radio connected to Microwave radio stations supported over digital data backbone ⋏ Cellular infrastructure supported on mobile or fixed BTS: GSM/GPRS/CDMA/UMTS/TDS-CDMA ⋏ No terrestrial infrastructure (Range<100m): 802.11g, Bluetooth, UWB; Possible future backup: 802.16 (<30 mi) ⋏ Mobile IP with IP terminals ⋏ No terrestrial infrastructure (Range>100m): LEO Satellite communications
	CM	OM-CSSB	Accept/ Reject ETD (expected time to delivery) Constraints	Text, Voice	⋏ The requirements for delivery such as expected time POC is sent to the OM-CSSB	
7	CM	PM	NSNs, Quantity, Order ID	Text, Voice	⋏ The specific list of consignments is sent so as to enable the IPM to reserve these products.	⋏ Voice radio connected to Microwave radio stations supported over digital data transmission ⋏ Cellular infrastructure supported on mobile or fixed BTS: GSM/GPRS/CDMA/UMTS/TDS-CDMA ⋏ No terrestrial infrastructure (Range<100m): 802.11g, Bluetooth, UWB; Possible future backup: 802.16 (<30 mi) ⋏ Mobile IP with IP terminals ⋏ No terrestrial infrastructure (Range>100m): LEO Satellite communications
	PM	CM	For all interactions/ transactions			
8	CM	xCM	For all interactions/ transactions			⋏ Voice radio connected to Microwave radio stations supported over digital data transmission ⋏ With Cellular infrastructure supported on mobile BTS (GSM/GPRS/CDMA/UMTS/TDS-CDMA) ⋏ Mobile IP with IP terminals ⋏ No terrestrial infrastructure (Range>100m): LEO Satellite communications ⋏ No terrestrial infrastructure (Range<100m): 802.11g, Bluetooth, UWB; Possible future backup: 802.16 (<30 mi)
	xCM	CM	For all interactions/ transactions			
9	xPM	xE	NSNs, quantity, packing rqmts, Time to pick-up, Priority	Text, Voice, Digital	⋏ The work order that contains the consignments to be made ready for delivery can be sent again as an e-form. The priority is a machine generated digital code.	⋏ Voice radio connected to Microwave radio stations supported over digital data backbone ⋏ Cellular infrastructure supported on mobile or fixed BTS: GSM/GPRS/CDMA/UMTS/TDS-CDMA ⋏ No terrestrial infrastructure (Range<100m): 802.11g, Bluetooth, UWB; Possible future backup: 802.16 (<30 mi) ⋏ Mobile IP with IP terminals ⋏ No terrestrial infrastructure (Range>100m): LEO Satellite communications ⋏ Hand-held 1-D, 2-D and RFID reader/recorder with Bluetooth ⋏ GPS enabled Satellite phones, Cellular phones; PDA and pocket PC terminals are available.
	xE	xPM	Accept/reject, availability	Text, Digital voice	-	
10	OM-CSSB	xE	Order ID, Location information, Encrypted	Text, Digital Voice	⋏ OM-CSSB shall continuously track the location information and assist E units with best routes	⋏ No terrestrial infrastructure (Range>100m): Satellite communications ⋏ No terrestrial infrastructure (Range<100m): 802.11g, Bluetooth, UWB; Possible future backup: 802.16 (<30 mi) ⋏ Mobile IP with IP terminals within FSSG ⋏ Voice radio connected to Microwave radio stations supported over digital data transmission ⋏ Cellular infrastructure supported on mobile or fixed BTS: GSM/GPRS/CDMA/UMTS/TDS-CDMA ⋏ Hand-held 1-D, 2-D and RFID reader/recorder with Bluetooth ⋏ GPS enabled Satellite phones, Cellular phones; PDA and pocket PC terminals are available.
	xE	OM-CSSB	Order ID, Location information, Encrypted	Text, Digital Voice	⋏ Updates on location information in transit	
11	FSSG	MLC	Order ID, Location information, Encrypted, Expected time for replenishment	Text, Digital Voice	⋏ FSSG shall place the order to MLC, in case stocked items are depleting and are not in stock. It may identify this request with a different Order ID, valid between MLC and FSSG only.	⋏ LEO/ MEO/GEO Satellite communications RFID and bar code can be used for asset tracking; start with pallet level and high value items using UID
	MLC	FSSG	NSNs, Quantity, Order ID, Location information, Encrypted, Expected time for delivery	Text, Digital Voice	⋏ Delivery status for Order ID is informed back to FSSG. ⋏ May also request for location information in case of mobile FSSG.	⋏ LEO/MEO/GEO Satellite communications RFID and bar code can be used for asset tracking; start with pallet level and high value items using UID

6.3 Satellite Communications Options

A number of satellite communications providers are available to select from, for the connectivity between SU ↔ RM, RM ↔ OM-CSSC, OM-CSSC ↔ OM-CSSB, FSSG ↔ MLC and connectivity with E. These are Iridium, GlobalStar, OrbComm, Thuraya, Inmarsat, ACES, Eutelsat, and AMPS. USMC is using the services of Iridium only in the Iraq war. As discussed earlier, LEO satellite systems have distinct and useful advantages over MEO and GEO satellite systems. Among these, Iridium, GlobalStar, OrbComm are LEO satellite systems. For more information on technical specifications of these satellite systems, refer to Appendix 10.4 Interim Report 2 (Appendix 9.4 Section 6.5.2). Listed below are the voice and data capabilities of these systems.

A. Iridium: LEO
1. Voice
2. Data
    × Dial-ups: 2.4Kbps
    × Direct Internet data: 10 Kbps
    × Short Burst Data Service: Message size of 1960 bytes / message (MO) and 1890 bytes / message (MT)
3. Fax

B. GlobalStar: LEO
1. Voice: Adaptive 2.4/ 4.8 / 9.6 Kbps
2. Date: 9.6 Kbps
    × High data rate (up to 144Kbps) products are available
3. Short messaging support (SMS)
4. Position location (accuracy up to 6 miles)

C. Inmarsat
1. Voice: 64Kbps
2. Data: 64 Kbps

D. Thuraya
1. Voice
2. Fax: 9.6 Kbps
3. Data: 9.6 Kbps
4. SMS
5. Location determination (GPS)

E. OrbComm: LEO
1. Messaging Services (data rates)
    × 2.4 Kbps subscriber uplink
    × 4.8 Kbps subscriber downlink
    × 9.6 Kbps subscriber downlink (future)

F. Eutelsat
1. Voice
2. Data: 4.8Kbps

Multi-Mode, Multi-Technology Devices
This section describes the handsets/terminals available today for supporting the communication on various links in the USMC logistics chain.

Combined Satellite/ Cellular Phones
1. *Ericsson "R190":* Handheld operates in *Satellite* and *GSM 900* modes.
2. *Hughes Thuraya "HNS-7100":* Phone combines *Satellite, GSM* and *GPS*. It supports both fax and data services, along with voice. Data rates supported are 2.4Kbps to 9.6 Kbps via V.24/V.28 modems. This phone also supports short message services and voice mail. This phone is a useful candidate for SU ↔ RM, RM ↔ OM-CSSC, OM-CSSC ↔ OM-CSSB and OM ↔ E connectivity.
3. *Qualcomm "GSP 1600 tri-mode":* A *CDMA digital, North America analog (AMPS)* and *Satellite,* Voice and data phone. Support Internet access at 9.6 Kbps from a laptop or a PDA connected to terminal with a single data cable.
4. *Telit dual-mode: GSM and satellite* phone

GPS Enabled Cellular Phones
1. *SiRF Technology Inc., and Benefon:* GPS-enabled dual-band GSM 900/1800 cellular phones. A good candidate for communications between various nodes within FSSG.
2. *QUALCOMM Incorporated's gpsOne(TM):* The claim is that gpsOne enabled wireless positioning (which uses both satellite and land based technologies [from CDMA networks] simultaneously) gives more precise and accurate location information than traditional GPS or network-based location solutions. The gpsOne A-GPS solution even works indoors and in dense urban canyons.

GPS Enabled PDA
1. *Garmin International "iQue 3600":* PDA with an integrated GPS technology.
2. *Adcom Group:* Windows CE powered PDA equipped with GPS positioning and GSM mobile phone technology. Terminal will also have Bluetooth antenna.
3. *Motorola "HDT600":* Handheld PDA for mobile messaging, queries and Computer Aided Dispatch. This terminal can simultaneously have a variety of options, including built-in bar code scanner, Bluetooth radio, and GPRS radio, all with internal antennas.

GPS Enabled Pocket PC
1. *Mio 168:* A very compact portable GPS voice-enabled navigation system, and the GPS device to run the Pocket PC operating system (using Microsoft's Windows Mobile 2003 Pocket PC).

Two-Way Portable Radios
1. *Kenwood's ProTalk TK3100:* Offers UHF/VHF portable radios for on-site communication needs for up to 5 miles
2. *Motorola Astro Digital series & CLS series* 2-way phones have many useful capabilities:
  ⅄ Mixed Analog/Digital Communication
  ⅄ Enhanced Encryption
  ⅄ Narrow Band Operation
  ⅄ Data capabilities (Alphanumeric Text Service)

There are other companies such as Nokia, Ericsson, and Freecom Wireless that are developing dual GPRS/ 802.11a/b WLAN data modem cards for personal computers, with no circuit switched voice capabilities. 802.16 and 802.20 are now being transitioned from the lab environments to field test and, pending successful field tests, should be available for commercial usage in the next 3-6 years.

Institute of Electronic and Electrical Engineers (IEEE) 802.16 Standard
IEEE 802.16 defines the WirelessMAN^{TM} air interface specifications for wireless Metropolitan Access Network (MAN). Standard describes the introduction of Broadband Wireless Access, targeting integrated voice, data and video services, connecting businesses to core telecommunications networks worldwide. Using wireless MAN, network access to buildings is provided through exterior antennas communicating with central radio base stations. Within the building, users can connect to an antenna receiver (or concentrator) using conventional Ethernet (IEEE 802.3) or Wireless LAN (IEEE 802.11) standards.

IEEE 802.16, also known as WiMAX, is essentially a point-to-multipoint wireless access standard for systems in the frequency range 10 - 66 GHz. Various licensed frequencies that have been identified for operation in this wide band are 10.5, 25, 26, 31, 38 and 39 GHz. Standard defines both physical layer and MAC layer specifications, and given the nature of services that it is expected to provide—for example, TDM voice and data, normal TCP/IP connectivity and packetized VoIP—MAC has been designed to accommodate both burst and continuous traffic. Development of this standard for operation between 10 and 66 GHz poses significant deployment challenges such as LOS requirements for supporting high data rates on both uplink and downlink. An extension, IEEE802.16a, has been developed for lower frequencies (between 2 and 11 GHz). This extension provides an opportunity to reach many more customers less expensively, although at generally lower rates.

The maximum achievable data rate with this standard is 120 Mbps duplex communications within a range of 30 miles for stationary mobile terminals. Refinements for supporting mobility are in the research phase.

WiMAX, an organization whose purpose is to promote deployment of broadband wireless access networks by using a global standard and certifying interoperability of products and technologies, supports IEEE 802.16.

IEEE 802.20
IEEE 802.20 describes specification for efficient packet-based air interface for optimized transport of IP-based services in MAN environments. The main objective for the development of this standard is to support IP services in Mobile Broadband Wireless Access (MBWA) networks. The specification defines both physical and medium-access control layers, in keeping with the traditional IEEE 802 development model. The frequency band for operation is in licensed bands below 3.5 GHz with a typical channel bandwidth less than 5 MHz, optimized for IP-data transport, with peak data rates per user in excess of 1 Mbps. It supports various vehicular mobility classes up to 250 km per hour in a MAN environment and targets spectral efficiencies, sustained user data rates and numbers of active users that are all significantly higher than achieved by existing mobile systems.

Various other characteristics of IEEE 802.20 are transport support for real-time and non real-time applications, support for inter-technology roaming and handoff (e.g., from 802.20 to 802.11 networks), co-deployment with cellular systems, universal frequency reuse, and QoS support.

6.4 Wireless Solution for Maintenance Scheduling: Proof-of-Principle Design and Development

The sections above describe a host of wireless communication technologies that can be used. In order to show the feasibility of implementation we have selected (*after discussion with Lt. Col. Lermo and Mr. Dave Lick*) maintenance use cases (OA- Compact Disc) as a basis for developing the proof-of-principle system. This proof-of-principle system developed and implemented at the *Laboratory for Intelligent Systems and Quality* (LISQ) at PSU Industrial Engineering Department uses the 802.11x wireless LAN for communication between PDA, desktop computers and the web server. Several futuristic maintenance scenarios were envisioned, the details of which can be found in Appendix 9.2. From these we have selected one specific scenario (Figure 6.6). For this scenario, we have identified and implemented relevant databases for maintenance scheduling, following the principles of distributed design and development. The details of information flows through Graphical User Interfaces (Screen-flows, PDA-User Interface) and the relevant databases are in Appendix 9.2.

6.5 Maintenance Scenario

A critical analysis of the operational architecture shows that the key issue for maintenance is Service Discovery. When a supported unit sends a request, the requirements such as manpower, inventory and facilities have to be first identified. Once the resources are identified decisions have to be made on how to optimally utilize them so as to fulfill the request. Scenarios presented in this section and Appendix 9.2 were further refined through discussions with the USMC personnel.   The refined scenarios capture the following USMC organizations:

- FSSG: The FSSG performs Intermediate and Depot level maintenance. This organization includes inventory, facilities and manpower, OM team, and an Expert who does resource allocation.
- CSSE Det: This organization includes an Expert who handles resource allocation, Inventory, Manpower, facilities.
- The request received by the CSSE Det is restricted only to its units that it supports, whereas a FSSG receives a copy of requests sent by all the units.
- The SU: identifies its requirements and submits requests to the CSSE Det and FSSG.

Scenario: 1 - This scenario represents the case in which all the resources namely manpower, facilities and inventory are all available within the CSSE Det. Figure 6.6 shows a step-by-step information and physical flow until fulfillment.
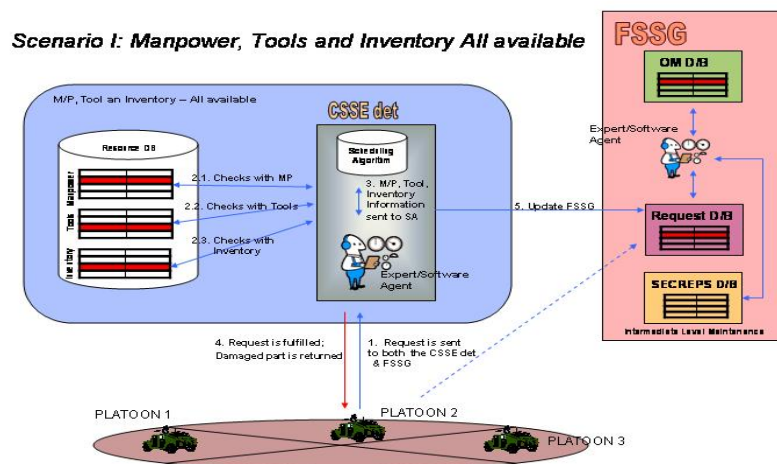
Figure 6.6: Scenario Showing the Origin of Maintenance Request until Fulfillment

In this scenario the resources that are required to fulfill the request are all available within the CSSE Det. Other cases that have been identified are presented as scenarios 2, 3, and 4 in the Appendix 9.2.

6.5.1 Implementation Framework - System Architecture

The systems architecture view describes various subsystems considered and the connections among them. The systems architecture view may be used for many purposes, including, for example, making investment decisions concerning cost-effective ways to satisfy operational requirements, and evaluating interoperability improvements. A systems architecture view addresses specific technologies and "systems." These technologies can be existing, emerging, planned, or conceptual, depending on the purpose that the architecture effort is trying to facilitate (e.g., reflection of the "as-is" state, transition to a "to-be" state, or analysis of future investment strategies).
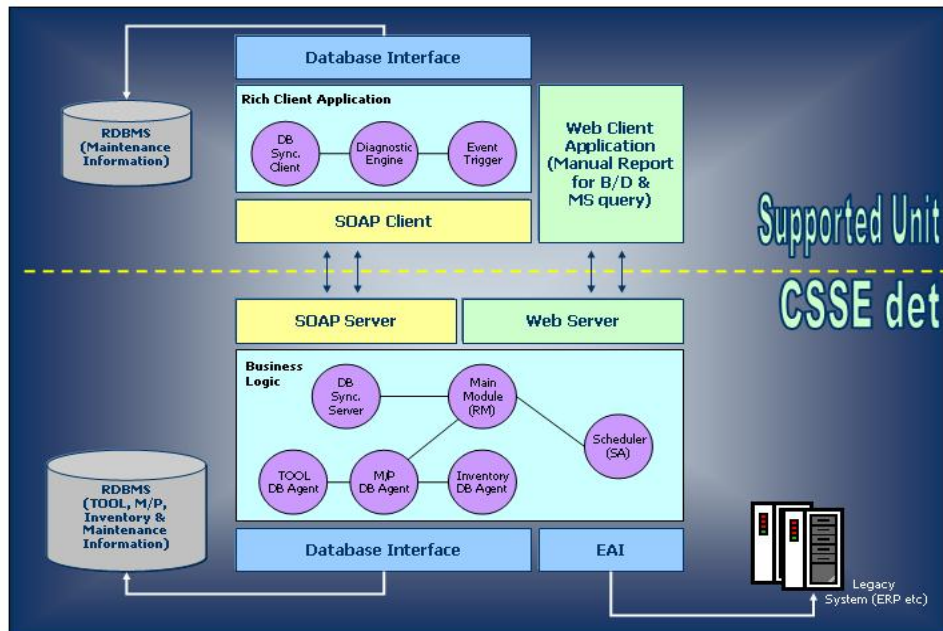
Figure 6.7: Systems View for Supported Unit and CSSE Det
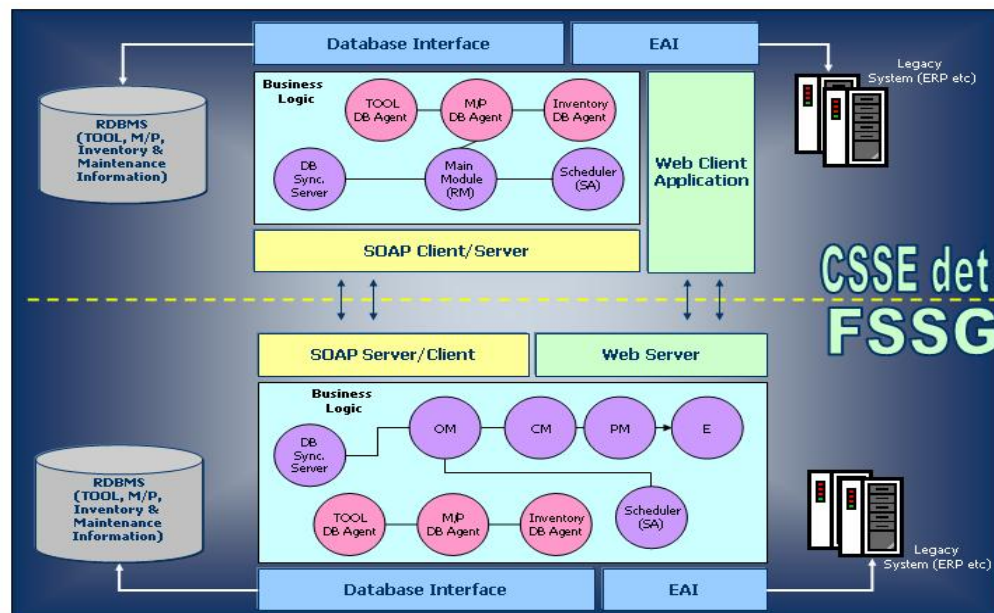
Figure 6.8: Systems View for CSSE Det and FSSG

Figures 6.7 and 6.8 show the system details and form the basis of the web based transactional proof-of-principle system. The implementation uses an n- tier architecture, which includes
- the presentation layer
- the business logic
- the data layer

6.5.2 Technical Architecture for Proof-of-Principle System [3], [4], [5], [6], [7]

Scenario for Implementation - The proof-of-principle system considers five actor types; Light Armored Vehicle (LAV) Operator, Web Server, Main Database, Maintenance Scheduling Algorithm, and Mechanic. The LAV sends a maintenance request through the Web-Application Server (WAS) for repair or replacement of a part. This request will be stored in a database by WAS. At the same time, WAS notifies the maintenance scheduling server about the new request. Using the request information, maintenance-scheduling server creates a new schedule for a specific mechanic. At that time, resource availability, required mechanic skill, and related resource information are considered for creating the new schedule. Resources could be manpower, tools, inventory and facilities.

Technical Architecture - Figure 6.9 shows the technical architecture for the proof-of-principle system.

- Web Application Server
  - Dell Dimension^{TM} 2400 desktops
  - Windows XP Professional
  - Java Developer Kit 1.4.2
  - Apache Tomcat 5.0.9
  - Java Server Pages
- Database Server
  - Dell Dimension^{TM} 2400 desktops
  - Windows XP Professional
  - MySQL 4.0.18
- Maintenance Scheduling Server
  - Dell Dimension^{TM} 2400 desktops
  - Windows XP Professional
  - Java Developer Kit 1.4.2
- PDA for Mechanic
  - DELL AXIM X5
  - Windows Pocket PC 2003
  - Internet Explorer for Pocket PC
- PDA for LAV Operator
  - DELL AXIM X5
  - Windows Pocket PC 2003
  - Internet Explorer for Pocket PC
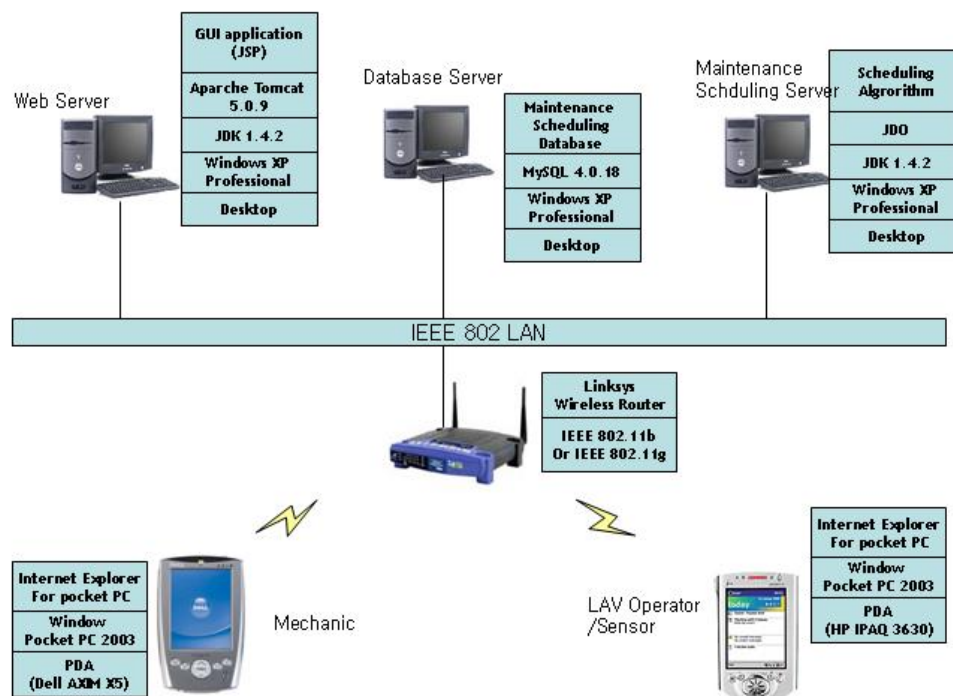
Figure 6.9: Technical Architecture for the Proof-of-Concept System

Refer Appendix 9.2 to see the implementation details.

6.5.3 Current Maintenance Practice USMC - Overview

The current maintenance procedures use paper-based forms such as equipment repair order (ERO), equipment repair order shipping/transaction list (EROSL) etc. These are used for requisition purposes and are forwarded to the specific maintenance units by manual means. The data contained in these forms are later entered into the relevant maintenance systems such as MIMMS, Field Maintenance Subsystems etc., for keeping records and maintaining visibility. Table 6.2 shows the current maintenance data generated.

Table 6.2: Data Attributes Identified from ERO and EROSL

Data Attributes	Description
ERO	
ERO Number	Equipment Repair Order Number
Acceptance Information (Signature)	Signature of the person accepting the equipment
Acceptance Date (DRIS)	Date received in shop
Organization doing repairs	Name of maintenance shop performing the repairs
Echelon	Echelons of Maintenance
Serial Number	Serial Number of the Equipment
Authorization Information (Signature)	Signature of the person authorizing the work to be performed
Authorization Date	
Priority	Priority assigned to the ERO
ID Number	System ID
Nomenclature	Name and/or model number of equipment
Job Order Number (JON)	Job order number to be charged for the repair parts
Shop Section	Shop section code
Task Number (Item No.)	Serial number for task performance entered in numerical sequence
Description of Work	Brief description of each task
Labor Hours	Total labor hours to the nearest $1/10^{th}$ of an hour
Mechanic Information	Signature of the mechanic performing the repair
Job Status - Code	Code indicating the job status
Status Date	Date on which the status is entered

EROSL	
ERO Number	Equipment Repair Order Number
Unit ID	Unit name and number submitting the EROSL
Date Received	Date received in shop
Date (INIT)	Date the mechanic fills in the EROSL
Material usage code	Indicates the type of part requested (accessories, SECREPS)
Shop Section	Shop Section Code
Supply IP	
NSN	Appropriate NSN of part to be ordered

6.5.4 Marine Corps Future Logistics Systems

The future Marine Corps Logistics systems will use the OA developed by the USMC as their conceptual foundation. The OA elements are common across all the nine USMC functional areas. The specific functional area considered for the proof-of-principle system is maintenance. Three different maintenance Use Cases are identified within the OA and are as follows:

- Maintenance at SU
- Maintenance at Intermediate Maintenance Activity (IMA)
- Return of MRO to Stock

6.6 Efficient Data Schema and Wireless Technology

6.6.1 Java Data Objects (JDO) [8]

The JDO application-programming interface (API) is a standard interface-based Java model abstraction of persistence, developed as Java Specification Request 12 under the auspices of the Java Community Process. Application programmers use JDO to directly store their Java domain model instances into the persistent store (database). Alternatives to JDO include direct file I/O, serialization, JDBC, and Enterprise Java Beans (EJB), Bean Managed Persistence (BMP) or Container Managed Persistence (CMP) Entity Beans.

Benefits of using JDO:

Portability: Applications written with the JDO API can be run on multiple implementations without recompiling or changing source code.

Database independence: Applications written with the JDO API are independent of the underlying database.

Ease of use: Application programmers can focus on their domain object model and leave the details of persistence (field-by-field storage of objects) to the JDO implementation.

High performance: Application programmers delegate the details of persistence to the JDO implementation, which can optimize data access patterns for optimal performance.

Integration with EJB: Applications can take advantage of EJB features such as remote message processing, automatic distributed transaction coordination, and security, using the same domain object model throughout the enterprise.

6.6.2 Wireless

The utilization of portable computing and wireless communications provides an opportunity to significantly change and improve the logistics and operational readiness of the USMC. Wireless technology will play an integral role for the future success of the USMC war fighter. It has become clear to us over the course of the project that a number of scenarios exist where providing reliable wireless connectivity is likely to increase efficiency, provided the communication technology is secure, reliable and available under a variety of conditions.

Wireless devices and mobile business solutions have the power to make significant improvement in logistics chain management and fleet management. The key to leveraging wireless technology in these fields is a good understanding of the impact of wireless solutions. With wireless devices and tracking mechanisms, the logistics chain can be transformed from a reactive, digitally enabled, linear process to a proactive supply web that acts much like a nervous system. In this network, wireless devices allow the supply chain to instantly sense requirements, problems, or changes throughout the network. This access to real-time information will enable faster decision-making and greater communication among parts of the supply chain.

When introducing a wireless technology for the proof-of-principle system, we have to consider several attributes as follows:
- Coverage: Newer wireless technologies, even though mostly serve only metropolitan areas, were designed with wireless infrastructures covering larger and larger geographical areas with less required equipment, thus saving on the equipment and deployment cost. Discussions with military representatives have led to the opinion that scaleable range communications are at least as vital to the workings of OA as other metrics. The requirement of coverage at different geographical scales is important, and those technologies that offer seamless reception throughout wide ranges will be noted.

● Transmission Speeds / Data rates/Adequate functionality: Figures cited by wireless technologies regarding the transmission data rates supported can be misleading. Implemented coding, error correction and data re-transmission methods limits the overall data capacity available in a wireless channel/system. The transmission speeds are often less important than reliable figures on a network's throughput: the amount of message-specific data that reaches recipients in a given period of time. In some cases technologies offering fast transmission speeds may also provide fast throughput as well. However, evaluations should not only rely on transmission speeds alone. Transmission speed and throughput information are critical because they directly affect the efficiency of wireless communications systems.

● Scalability: Once installed, set up and working is the system able to increase load, without loss of performance? Was the system designed so that it can be re-scaled in a simple straightforward manner by maintenance personnel? If so, how does the scalability take place (use of plug and play modules or something else), what is the upper limit value of performance scalability? For example, how many channels or how many end users can simultaneously use the communication channels at 100% of data transmission usage?

● Susceptibility to interference: Each communication device must be specified and tested for the following interference types: conductivity, susceptibility and radiated emissions. Conductivity tests the units ability to handle induced noise being power-supplied; susceptibility is the ability of the unit to handle radiated emissions from neighboring equipment or other interference signals from the outside world; radiated emissions is that quantified amount of power which your system emits as interference either nearby or far.

● Maintainability: Often overlooked or last to be completed are maintainability and system logistics needs. What levels of maintenance are needed? What is the Mean Time to Repair? What training or aptitude skills are necessary by the war fighter to maintain the system? What parts will be repaired at depot or disposed when found to be unserviceable?

Based on discussions in Sections 6.5.1 and 6.5.2, we here present a solution methodology for efficient maintenance scheduling below.

6.7 Solution Methodology for Maintenance Scheduling

Scheduling Overview - A Scheduling Agent must perform three steps to schedule a maintenance activity.
  1) Diagnosis: the request must be diagnosed to determine
      a. Tasks which must be performed.
      b. Parts needed.

      c. Tools needed.

      d. Personnel skill level required.

2) Compilation: a maintenance activity allocates parts, tools and personnel.

      a. Priority of alert is reviewed.

      b. A time, date and location where LAV and supplies/personnel must meet.

3) Notification

      a. The LAV operator must be notified of when and where to meet.

      b. The Supply Unit(s) must be notified of when and where to send their supplies/personnel. It will be the responsibility of the Supply Unit to reserve the required supplies and update their inventories.

      c. If a request was unable to be scheduled (due to resource constraints), the LAV operator must be notified that the request has been put into a queue.

Due to the distributed nature of the supply units, a multi-agent based scheduling process (Figure 6.10) is necessary.
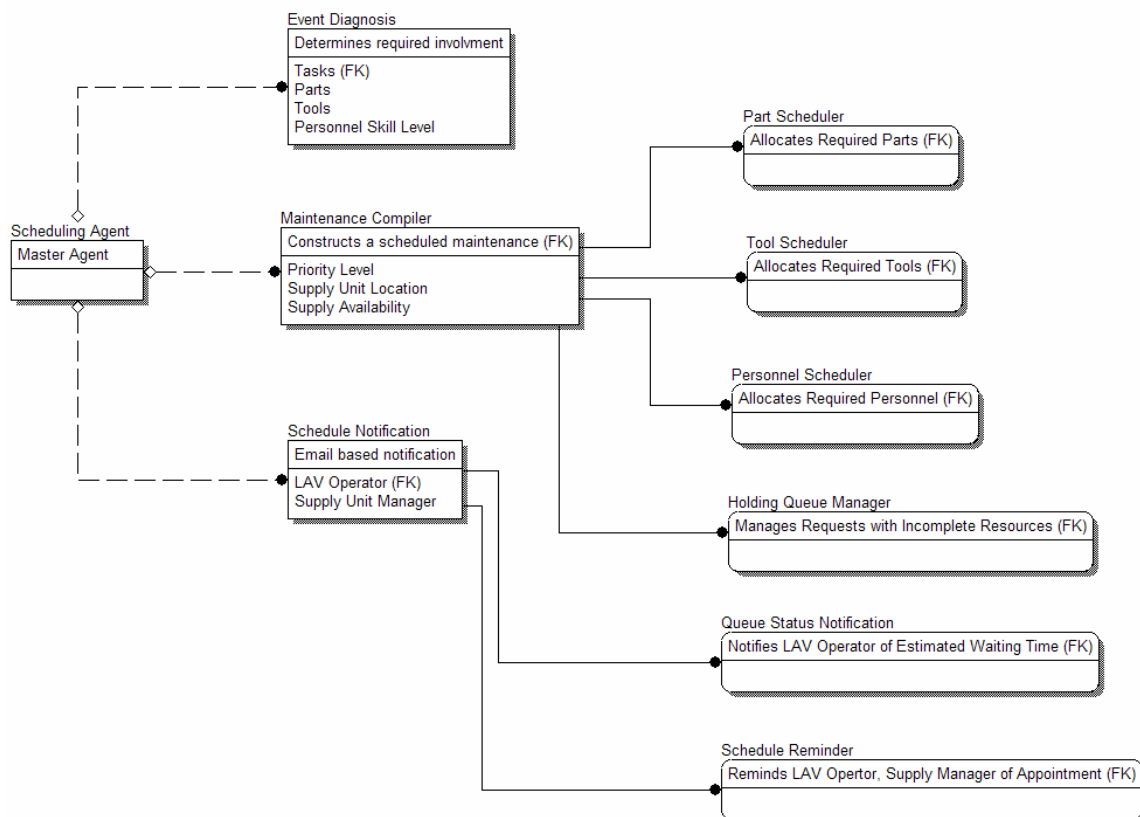
Figure 6.10: Multi-agent Based Scheduling Process

Diagnosis: In order to diagnose an event, the Scheduling Agent must receive the following information.

      a. Identification No. of LAV (vin_no)

b. Identification No. of Requester (this could be the LAV operator or a mechanical sensor)
c. Date when the Breakdown Occurred (date_occurred)
d. Date when the Request was sent (date_requested)
e. Priority of the Request (alert_type)
f. Nature of the Breakdown (breakdown_code)

With the above packet of information, the Scheduling Agent will then determine the tasks required to complete maintenance. Each one of those tasks may require separate parts/tools/manpower, and they must be performed in a specified order.

The following schematic Figure 6.11 can be used to determine the tasks and required supplies:
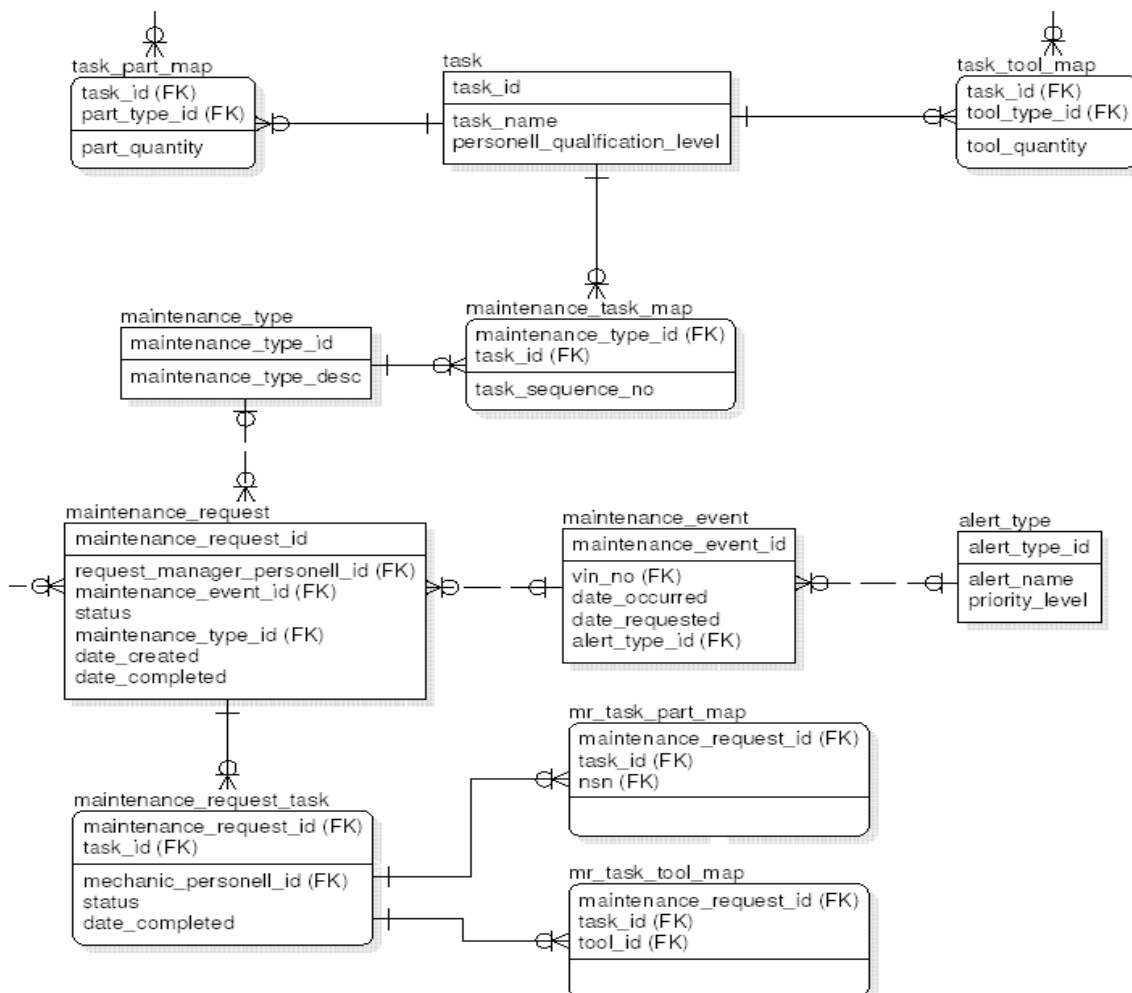
Figure 6.11: Schematics to Determine Task and Supplies

Compilation: Once the breakdown/maintenance request is diagnosed and the specific tasks have been determined, the Scheduling Agent must assign supplies and personnel to each specific task. This is a complex scheduling task because

the supplies can be located in multiple supply units. The complexity is introduced when different supply units store their supply data in different formats. One unit may use a spreadsheet. Another unit may use a relational database, or perhaps even a note based messaging system. This is referred to as a federated data source because it is made up of multiple heterogeneous components. However, even though the format of the information is different, the information domains are the same. The three domains of information we are concerned with are Inventory/parts, Tools, Facilities and Manpower.

The Scheduling Agent is not responsible for inventory management or personnel availability. These tasks are left up to the individual Supply Units. The Scheduling Agent leaves the assigning of each of these components to an autonomous agent. These agents can utilize a simple reference schematic (Figure 6.12) to allocate these resources as follows:
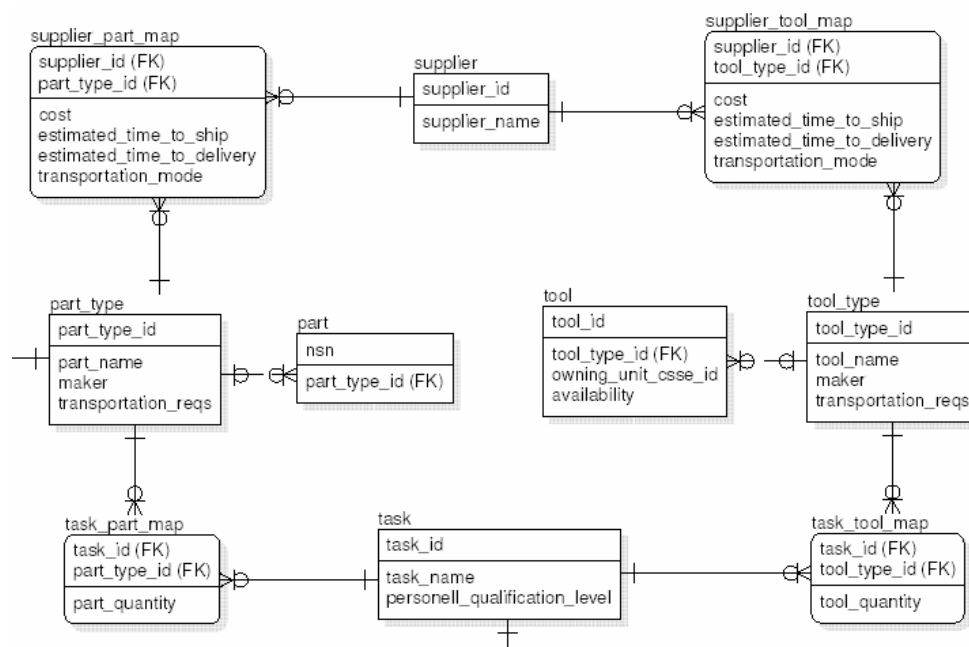
Figure 6.12: Schematics for Resource Allocation

6.8 Maintenance Compiler Process Flow

(1) Each autonomic agent queries an integrated collection of heterogeneous data sources in eligible Supply Units for the required
        a. Inventory
        b. Tools
        c. Facilities
        d. Skilled Manpower

(2) IF: All maintenance request (MR) components are available, go to Step 3
   ELSE: Agent must:
   a. Issue an order request from the most eligible Supply Unit
   b. Add MR to a queue of unfulfilled MRs
   c. Listen for a fulfillment notification from the designated Supply Unit
   d. Once fulfillment notification is received, remove MR from queue and repeat Step 1.

(3) Maintenance Compiler reserves each allocated supply and stores the details of each task involved in the maintenance in a database.

Notification: Proper notification of each stage in the scheduling process is required in order to ensure that separate parts of the maintenance (LAV, Supplies, and Personnel) all arrive on time for the tasks to take place. The medium for the notification will optimally be an email message, sent to the PDA of the LAV Operator, or the mailbox of the Supply Manager(s).

The Scheduling Agent assigns the task of Notification to a slave agent known as the Schedule Notification. This slave agent is responsible to notify the following:

Outgoing Notifications:

- LAV Operator
  a. Time/Date of a Scheduled Maintenance
  b. Status of a Maintenance Request (position in queue)
  c. Reminder of a Scheduled Maintenance
- Supply Manager
  a. Time/Date of a Scheduled Maintenance
  b. Parts, Tools and/or Skilled Laborers from Unit who have been assigned
  c. Status of a Maintenance Request (position in queue)
  d. Reminder of a Scheduled Maintenance

Incoming Notifications:

- Mechanic
  a. Completion of a Maintenance Task
  b. Failure of a Maintenance Task
- LAV Operator
  a. LAV will not arrive on time for a Scheduled Maintenance
  b. Priority level of request has changed
- Supply Unit
  a. Part/Tool/Personnel will not arrive on time for a Scheduled Maintenance

      b. Part/Tool has arrived (due to a reorder request from the Scheduling
         Agent)

Federated Data Schemas:

From looking at the Scheduling Agent Process Flow above, it is apparent that the
following schemas will be necessary to track the Process Flow as it is written.

- Maintenance Reference Data
  - a. Used by Agent to compile an MR (info on Repair Procedures)
  - b. Subset used by LAV to compile an ME (info on Alerts, Parts, Operators)

- Scheduled Maintenance Data
  - a. Contains all of the Scheduled Maintenances which have been created by the Agent. The only entity, which should have access to this schema is the Scheduling Agent (unless an alternate entity updates the completed maintenances – see assumption 1 above).

- Supply Unit Data
  - a. This is not a physical database. It is a heterogeneous collection of the data sources from each of the Supply Units. It is a Federated Database Management System. The schema for this federation needs to be identified so that the appropriate model can be put in place to integrate the federation and make it accessible to the Scheduling Agent as one consolidated source of Supplies.

Included in the Supply Unit Data will be important information regarding LAV
status as well as Personnel status. The Scheduling Agent can define the
integration of these separate information domains using its own interpretation of
the federation.

For the LAV information, the Scheduling can view the Information domain as
having the following schematic as shown in Figure 6.13.
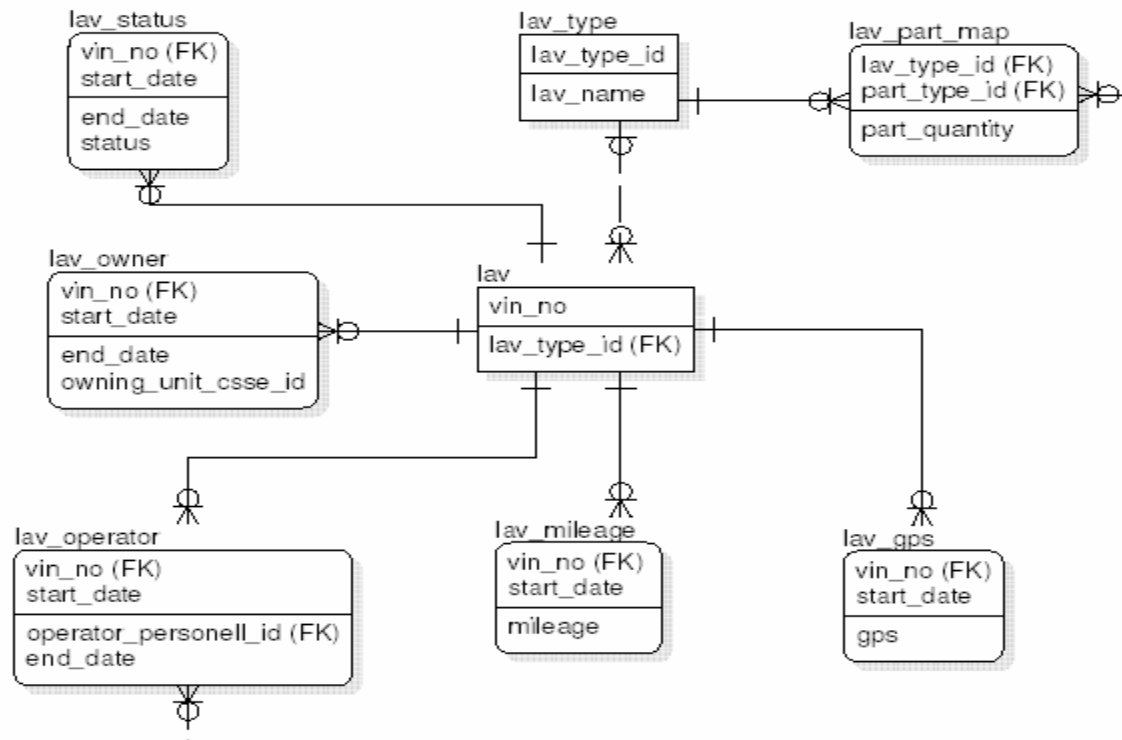
Figure 6.13: Information Domain for LAV

For the Personnel Management, the Scheduling can view the Information domain as having the following schematic as shown in Figure 6.14.
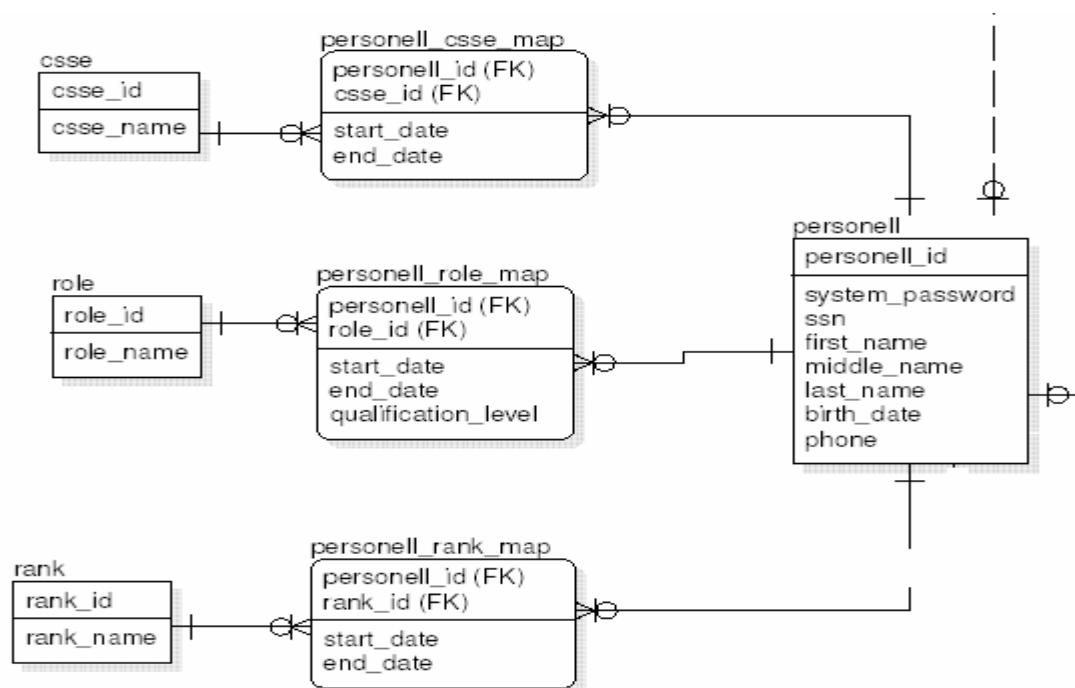
Figure 6.14: Information Domain for Personnel Management

7 Determine Impacts of Implementation

Task 6: Determine impacts of implementation
6.1: Determine the impact of portable/wireless technology implementation on the attributes defined within the OA (reliability, expenses, responsiveness etc.) as they apply to the selected processes. Where mutually agreed to between Penn State and the Sponsor, provide recommended future development insertion where appropriate.

The implementation of wireless technologies for the USMC future logistics systems will impact various operational processes. In the sections below we briefly describe the implications with respect to communication networks, information systems and other functions such as inventory tracking.

7.1 Impacts on Information Systems and Networks

7.1.1 Distributed vs. Centralized Information Processing

One of the key issues when using portable devices for enterprise wide transactions is to be able to update the relevant databases within a distributed environment. The various actors using the handheld devices will be accessing the same data at different points in time. If the databases are not updated instantly, the next user might receive wrong information. Therefore, the change in information that occurs due to a particular transaction has to be updated in a timely manner (near real-time).   As this information mostly is distributed, all relevant systems have to be simultaneously notified. This could dramatically reduce the communication speed across the network. On the contrary, if all information were to be stored in a centralized repository then many of the supported units that are physically far from this location might find it difficult to connect to the database/system. When designing a wireless network and integrating it with the information systems, it is important to determine the optimal topology of the network. This currently is an open research problem and further analysis is required to determine the context specific network topology.

7.1.2 Communication Loads

The computations for bandwidth across different links that have been done currently are based on the statistics supplied by the USMC personnel. In future as more services are added to the CSS functions these requirements may prove insufficient. The allowance in capacity that needs to be given to the networks that will be developed has to be determined after rigorous analysis and accurate forecasts for future communication loads.

7.1.3 Survivability

Owing to the highly dynamic environment in which these systems will be used, survivability of the network becomes critical. Since the Marine Corps plan to use commercially available services for communication, the networks can be disrupted by destroying the base stations. One method to improve survivability is to increase redundancy in communication paths, so that the user will have alternatives even if a single link is cut off. This once again is an issue that is being researched by both academia and industry. Specific standards for survivable communications networks may not be developed in the near future. Therefore during deployment the USMC personnel would need to ensure that the network being designed carries sufficient redundancy in communication paths and will function even after considerable damage.

7.1.4 Security

An important aspect with military systems is the security of information. Mechanisms must be put into place to ensure privacy, confidentiality, identity, and controlled access to services. The following technologies can be integrated to provide a secure wireless environment. The security issues with regard to specific technologies and probable solutions are discussed below.

Most of this information is extracted from the references [9], [10], [11] listed.

Overview

The IEEE 802.11 specification identified several services to provide a secure operating environment. The security services are provided largely by the Wired Equivalent Privacy (WEP) protocol to protect link-level data during wireless transmission between clients and access points. WEP does not provide end-to-end security, but only for the wireless portion of the connection.

The three basic security services defined by IEEE for the WLAN environment are as follows:

- **Authentication:** A primary goal of WEP was to provide a security service to verify the identity of communicating client stations. This provides access control to the network by denying access to client stations that cannot authenticate properly. This service addresses the question, "Are only authorized persons allowed to gain access to my network?"
- **Confidentiality:** Confidentiality, or privacy, was a second goal of WEP. It was developed to provide "privacy achieved by a wired network." The intent was to prevent information compromise from casual eavesdropping (passive attack). This service, in general, addresses the question, "Are only authorized persons allowed to view my data?"
- **Integrity:** Another goal of WEP was a security service developed to ensure that messages are not modified in transit between the wireless

clients and the access point in an active attack. This service addresses the question, "Is the data coming into or exiting the network trustworthy— has it been tampered with?"

Problems with IEEE 802.11 Standard Security

Security problems with WEP include the following:
- The use of static WEP keys—many users in a wireless network potentially sharing the identical key for long periods of time, is a known security vulnerability. This is in part due to the lack of any key management provisions in the WEP protocol. If a computer such as a laptop were to be lost or stolen, the key could become compromised along with all the other computers sharing that key. Moreover, if every station uses the same key, a large amount of traffic may be rapidly available to an eavesdropper for analytic attacks, such as two following issues.
- Initialization Vector (IV) in WEP is a 24-bit field sent in the clear text portion of a message. This 24-bit string, used to initialize the key stream generated by the RC4 algorithm, is a relatively small field when used for cryptographic purposes. Reuse of the same IV produces identical key streams for the protection of data, and the short IV guarantees that they will repeat after a relatively short time in a busy network. Moreover, the 802.11 standard does not specify how the IVs are set or changed, and individual wireless NICs from the same vendor may all generate the same IV sequences, or some wireless NICs may possibly use a constant IV. As a result, hackers can record network traffic, determine the key stream, and use it to decrypt the cipher-text.
- The IV is a part of the RC4 encryption key. The fact that an eavesdropper knows 24-bits of every packet key, combined with a weakness in the RC4 key schedule, leads to a successful analytic attack that recovers the key, after intercepting and analyzing only a relatively small amount of traffic. This attack is publicly available as an attack script and open source code.
- WEP provides no cryptographic integrity protection. However, the 802.11 MAC protocol uses a non-cryptographic Cyclic Redundancy Check (CRC) to check the integrity of packets, and acknowledge packets with the correct checksum. The combination of non-cryptographic checksums with stream ciphers is dangerous and often introduces vulnerabilities, as is the case for WEP. There is an active attack that permits the attacker to decrypt any packet by systematically modifying the packet and CRC sending it to the AP and noting whether the packet is acknowledged. These kinds of attacks are often subtle, and it is now considered risky to design encryption protocols that do not include cryptographic integrity protection, because of the possibility of interactions with other protocol levels that can give away information about cipher text.

Note that only one of the four problems listed above depends on a weakness in the cryptographic algorithm. Therefore, these problems would not be improved

by substituting a stronger stream cipher. For example, the third problem listed above is a consequence of a weakness in the implementation of the RC4 stream cipher that is exposed by a poorly designed protocol.

Solutions

Technical solutions involve the use of hardware and software solutions to help secure the wireless environment. Software countermeasures include proper AP configurations (i.e., the operational and security settings on an AP), software patches and upgrades, authentication, intrusion detection systems (IDS), and encryption. Hardware solutions include smart cards, VPNs, public key infrastructure (PKI), and biometrics. It should be noted that hardware solutions, which generally have software components, are listed simply as hardware solutions.

- Software Solution: Technical countermeasures involving software include properly configuring access points, regularly updating software, implementing authentication and IDS solutions, performing security audits, and adopting effective encryption.
  - Access Point Configuration
  - Authentication
  - Personal Firewalls
  - IDS
  - Encryption
  - Security Assessments
- Hardware countermeasures for mitigating WLAN risks include implementing smart cards, VPNs, PKI, biometrics, and other hardware solutions.
  - Smart Cards
  - VPN
  - PKI
  - Biometrics

Security of Wireless Personal Area Networks (Bluetooth)

Overview

Ad hoc networks today are based primarily on Bluetooth technology. Bluetooth is an open standard for short-range digital radio. It is touted as a low-cost, low power, and low profile technology that provides a mechanism for creating small wireless networks on an ad hoc basis. Bluetooth is considered a wireless PAN technology that offers fast and reliable transmission for both voice and data. Untethered Bluetooth devices will eliminate the need for cables and provide a bridge to existing networks. Bluetooth can be used to connect almost any device to any other device. An example is the connection between a PDA and a mobile phone. The goal of Bluetooth is to connect disparate devices (PDAs, cell phones, printers, faxes, etc.) together wirelessly in a small environment such as an office

or home. Bluetooth is designed to operate in the unlicensed ISM (industrial, scientific, medical applications) band that is available in most parts of the world, with variation in some locations. Bluetooth-enabled devices will automatically locate each other, but making connections with other devices and forming networks requires user action.

Security for Bluetooth is provided on the various wireless links—on the radio paths only. In other words, link authentication and encryption may be provided, but true end-to-end security is not possible without providing higher layer security solutions on top of Bluetooth. In the example provided, security services are provided between the PDA and the printer, between the cell phone and laptop, and between the laptop and the desktop. Briefly, the three basic security services defined by the Bluetooth specifications are the following:

- **Authentication:** A goal of Bluetooth is the identity verification of communicating devices. This security service addresses the question "Do I know with whom I'm communicating?" This service provides an abort mechanism if a device cannot authenticate properly.
- **Confidentiality**—Confidentiality, or privacy, is another security goal of Bluetooth. The intent is to prevent information compromise caused by eavesdropping (passive attack). This service, in general, addresses the question "Are only authorized devices allowed to view my data?"
- **Authorization**—a third goal of Bluetooth is a security service developed to allow the control of resources. This service addresses the question "Has this device been authorized to use this service?"

As with the 802.11 standard, Bluetooth does not address other security services such as audit and non-repudiation. If these other security services are desired or required, they must be provided through other means. The three security services offered by Bluetooth and details about the modes of security are described below. Also worthwhile to note, Bluetooth provides a frequency-hopping scheme with 1,600 hops/second combined with radio link power control (to limit transmit range). These characteristics provide Bluetooth with some additional, albeit small, protection from eavesdropping and malicious access. The frequency hopping scheme, primarily a technique to avoid interference, makes it slightly more difficult for an adversary to locate the Bluetooth transmission. Using the power control feature appropriately forces any potential adversary to be in relatively close proximity to pose a threat to the Bluetooth network.

Problems with Bluetooth

Bluetooth offers several benefits and advantages. However, agencies must not only address the security threats associated with Bluetooth before they implement the technologies; they must also assess the vulnerabilities of the devices they allow to participate in the Bluetooth networks. Specifically, agencies need to address security concerns for confidentiality, data integrity, and network availability. Moreover, since Bluetooth devices are more likely to be managed by users that are less security conscious than administrators, they are more likely to contribute to involuntary security lapses. This subsection will briefly cover some of the risks to security, i.e., attacks on confidentiality, integrity, and network availability.

Solutions

As with WLANs, Bluetooth technical countermeasures fall into one of two categories: software security solutions and hardware security solutions. Bluetooth software solutions focus on PIN and private authentications, while hardware solutions involve the use of the Bluetooth device address and link keys that reside at the link level. Again, it should be noted that hardware solutions, which generally have software components, are listed simply as hardware solutions.

7.1.5 Ubiquitous Computing

Overview

 When mobile computing and intelligent environments are used together, the full potential of ubiquitous computing is realized. This can be summarized in the "ubiquitous computing equation":

Ubiquitous Computing = Mobile Computing + Intelligent Environment

Ubiquitous computing allows several important scenarios that cannot be achieved by either mobile computing or intelligent environments alone:

- *Disaggregated Computing:* A dynamic reconfiguration of the set of user interface devices, for example the ability to make your display move to any screen in the room. Therefore, the "computer" is a virtually connected group of several devices that are actually attached to different physical computers on the network. Usually, each device has software "proxy" to represent that device in the software system.

- *Location-Sensitive Computing:* Making the computing experience change as you move around, for example a museum tour guide, or automatically making your display move the nearest screen as you

walk around the room. This requires a person-location sensor of some kind, such as a badge system or visual surveillance by cameras.

- *Augmented Reality:* One of the most interesting scenarios for wearable computers is when they are combined with location-sensitive information. Then, relevant information can be overlaid on the view of the world, which is seen through the head-mounted display. This is called "augmented reality", as opposed to "virtual reality" where *only* the computer-generated information is being viewed.

- *Object-Sensitive User Interfaces and Phicons:* Associating physical objects with information, such as associating an appliance with the web page for its manufacturer. If you bring your mobile computer to the appliance, you may view this information. "Phicon" means a "physical icon", i.e., associating meaning with an unrelated object which can then be given to another person or moved around, etc.

Long-Term Issues in Ubiquitous Computing

Ubiquitous computing introduces several new long-term issues that must be dealt with through careful design:

- *Privacy:* The proliferation of sensors and context models will store large amounts of information about people's activities. The more we want the system to help us automatically, the more information it needs. But, these collections of information may contain data that we do not want to distribute. How do we selectively allow some programs to use this information while preventing others?

- *Complexity:* The more things are happening automatically, the more confusing the system may be for the person in the room. How do we make the system's capabilities available without overloading the person's attention or understanding? Presenting information without demanding the user's attention is so important that it has been given a name of its own: "calm computing".

- *Extensibility:* Ubiquitous computing systems will be made of many pieces of hardware and software, from many sources. How do we enable them to work together at all levels from low-level communication to high-level task semantics?

- *Security:* If all things are connected, how do we prevent and limit attacks from unauthorized programs or hardware?

7.2 Impacts on Inventory Tracking – RFID Tags

- Early pilots, particularly at Norfolk Ocean Terminal suggest that human intervention will be needed to verify and validate RFID reads. Though RFID reduces time to read, accuracy must be checked, sometimes manually.
- Though RFID has not been proven clinically hazardous to human health through exposure, this issue continues to concern workers associated with the systems. Workers at Norfolk, for example, questioned the safety of working within these environments.
- Experience shows that systems co evolve. With the introduction of any wireless or RFID system, workers will begin to modify their former behaviors and to build new informal communication channels. Unfortunately, the wireless or RFID systems are frequently built on the workflow processes in place or anticipated. Systems such as these change the way that information flows, particularly its direct flow to lower levels in the organization. Workers at these lower levels, now informed, are apt to take on more decision making activities. This may be in direct conflict with traditional command and control structures of the military.
- Currently ERP systems and middleware offer solutions to data exchange and transfer, but commercial experience shows that these linkages are often not robust enough and thus, further investments in customization of software have been required. Careful discussions with vendors will help identify tracking needs and customization required.
- Current hand held readers are not as robust and procedures that work for fixed location readers (in garrison) will not necessarily work equally as well in the field with hand held readers. Some human in the system intervention or additional checking/monitoring of ID reads will be required in the field with hand held readers.
- To facilitate multiple types of reads throughout the supply chain, printers that generate a single bar code label with an embedded RFID code might be a practical solution to relabeling in transit.
- Before creating a unique system, the USMC should review the current Itronix system in Iraq for possible use in logistics and communication. This system has been developed from a commercial application platform, but with robust features added to address the harsh operating conditions in the field. Though the Sears system and other commercial applications are using the Itronix system for real time maintenance workforce scheduling, the configuration might prove useful to USMC needs.
- Some vendors offer RFID 'boot camp' to help planners anticipate needs and uses; others offer starter kits to help planners develop pilot implementations. Regardless of the start path, thought should be given to the roll out of RFID since it will have implication for the middleware needed at particular stages, the trouble shooting to anticipate, the robustness of the redundant

communication channels and software, and the human-in-the-system needs. If all is not in place prior to rollout, system performance will be degraded if commercial implementations are any guide.

8 Recommendations and Conclusions

Having analyzed the relevance of using wireless technologies and portable devices for the USMC logistics chain, the team identified the specific areas within the operational architecture where wireless technologies need to be used. The proof-of-principle system that has been implemented at the laboratory for Intelligent Systems and Quality (LISQ), at Penn State verified the feasibility of enabling the OA processes through wireless means. The critical segments within the OA processes that need to be enabled with wireless solutions are listed below. These form the main areas of focus for the USMC to proceed towards implementation and testing.

- Enable real-time requisitioning by implementing cellular communication between supported units, RM and OM
- Reduce the time to respond by enabling wireless communication between execution units and Production Management
- Increase asset visibility by identifying inventory items using wireless LANs and RFID mesh networks
- Use satellite communication as a backup to increase reliability in communication
- Enable intelligent preparation of the battlefield for logistics

We recommend that the USMC generate a strategic plan for proceeding towards implementation. To support this near term steps should include the following.

Develop a prototype to guide implementation of wireless solutions for the OA processes identified above. This requires enhancing and refining the proof-of-principle system that has been developed. The reliability of the wireless solutions needs to be tested in field environments. The specific decision support tools have to be defined and developed. In addition the system specifications should be refined along with performance metrics. The organizational impacts of implementing these wireless solutions have to be analyzed within the context of tactics, training, procedures and manpower.

The next section offers specific recommendations along three different perspectives, developing prototype system architecture, technical specifications for the wireless solutions and use of RFID for inventory tracking. Though some of these are mentioned in the Appendix 10.1 of this report, they are presented collectively for clarity and convenience.

8.1 Prototype System Architecture Recommendations

The proof-of-principle implementation made the team realize several issues. These led to the following recommendations regarding a prototype system development. It is necessary to build a prototype by enhancing the proof-of-principle system that has been implemented. This will help to come up with a detailed requirements specification for building the real large scale system. From the point of view of building a prototype the following are our recommendations:

1. Detailed transaction analysis of OA processes to generate more accurate data/information transfer
2. Evaluation of commercial wireless and web application technologies– J2EE, .NET, Oracle, SQL server 2000, SatComm, WAN based upon the results of 1
3. Prototype development
4. Evaluation of the prototype compliance to OA, integration with GCSS-MC and Sea-based Logistics
5. Requirements specifications for next generation system
6. Transition plans to next generation system

8.2 Technical Recommendations

To help meet the USMC proposed balanced scorecard Tier 1 metrics as found in the OA, the following items are recommended:

1. Reduce risk and increase reliability by using systems engineering processes in all USMC large-scale wireless systems acquisitions.

2. Use reliability engineering to increase the chances that wireless communications will work successfully in the *intended* USMC environment; include the following systems and logistic scorecard specifications:

General systems specifications:

- mean time between maintenance
- availability
- mean time between failures
- mean downtime
- mean time to repair
- mean time to fix
- overall reliability performance

Logistics specifications:

- operational availability
- quality order fulfillment
- total logistics chain expense
- total logistics chain cycle time
- logistics chain capacity
- asset utilization

3. Use Failure Modes, Effects and Criticality Analysis (FMECA); Use additional 6-sigma performance and decision making tools to help improve USMC logistics.

4. Use of Markov model approach to solving complex systems availability.

5. Validation and verification that the overall wireless systems minimum requirement performance specifications are satisfied:

- Using realistic field set-up, integration and testing
- Using, at a minimum, each of the following three test environments:

  a. Academia benign environment
  b. USMC proving test grounds
  c. Expeditionary USMC remote location and bare communications environment

6. Data analysis/data-mining pertaining to the "state of the USMC logistics metrics" during the Iraq war.

7. Pertaining specifically to RFID, further research involving:

- o Tag and reader interoperability
- o Country-specific regulations
- o IT Infrastructure requirements
- o RF properties, for example, with metals and liquids
- o RF properties with scattering and multipath
- o RF radiated emissions and electromagnetic susceptibility
- o USMC requirements and EPC-Supply Chain Performance Testing
- o USMC requirements and EPC-Compliant Systems and Systems Integration Standards
- o USMC requirements and EPC-Compliant validation and verification specifications
- o USMC needs vs. DoD performance requirements
- o USMC privacy, health & safety issues
- o USMC pilot programs with data analysis specifically showing ability of RFID system to accurately read and take inventory of goods such as pallets and individual cases
- o Optimal label placement

- o Performance validation in a realistic USMC environment, pertaining to the number of reads expected against number of reads achieved
- o Needed USMC workforce training in principles of RF and RFID
- o Statistical knowledge of collateral reads, data collision issues, unexpected reads caused by reflections
- o Knowledge of how to integrate tags and UID labels into unique packaging or parts

8. Focus on a USMC project intended to develop a reliable means of using primarily commercial off the shelf technology, to provide a seamless *intermodal* means of tracking and trace back of USMC logistics supplies, *worldwide*. This team would be made up of collocated academia and USMC logistics and field maintenance personnel.

9. Research the feasibility of using fuel cell technology in providing extended time-duration power for USMC expeditionary-fielded communication and other related wireless equipment.

10. Research and field-test the feasibility of using 802.16 wireless technology in remote logistics supply chain geographic locations.

11. Research and field-test additional commercial satellite communication systems other than Iridium. For example, GlobalStar and OrbComm. This test should also evaluate the use of commercial encryption and use of military encryption performance with the commercial satellite provider.

8.3 Operational Change Recommendations

1. **Semi-passive tags must be carefully deployed.** Semi-passive tags are battery assisted to improve read-range. However, batteries degrade in severe heat and so these tags introduce additional monitoring needs into any system to make sure that the batteries are in working order. The read-range boost must be considered in light of this additional monitoring.

2. **ERP system linkages will require web-based service oriented architecture.** The commercial system is going away from monolithic software solutions to modular solutions connected together with web services. Any USMC configuration should plan for this emerging flexibility.

3. **Inventory Tracking Recommendations:**
a. Items that can easily be scanned manually.

b. Items that must be scanned manually due to some material or other consideration.

4. Use read-only passive RFID for the following:

a. **Items that will never change their contents and which do not need to have additional information associated with them during transit.** These should be used for items that can easily be scanned by an RFID reader in a fixed location.

5. Use read-only passive RFID tags to track critical equipment within a fixed location (such as medical equipment being tracked within a hospital location or key maintenance equipment that might be shared among workers).

6. Use read/write passive RFID tags for the following items:

a. **Items that will not change their contents, but which may have additional temperature, time or other tracking recorded during transit.**

b. **Items whose contents may change during transit.** This might include pallets whose contents may need to be modified as items are removed and delivered in transit.

7. The trade-off between fixed location and mobile (hand-held) RFID readers.

a. **Use fixed location readers whenever accuracy is needed (with little or no manual backup).**

8. Use mobile (hand-held) RFID reader when mobile scanning is essential and when procedures are put into place to verify the reads in some way. Hand held devices are much less reliable (as much as a 78% read accuracy compared to 99% read accuracy of fixed location readers). The use of mobile devices must be carefully considered.

9. Use mobile (hand-held) bar code scanner when contents of bins or other larger containers needs to be tracked; consider voice activated pick-and-pull inventory for complex combinations of smaller items, or in environments where hands-free is important.

10. Carefully match item content, material composition, RFID tag protocol and reader hardware to ensure compatibility. Some items that will be tracked, as well as their packaging, will interfere or distort RFID signals, thus reducing read efficiency (time to read) and accuracy (correct content). Pilot trials have determined that tags and readers are not

interchangeable.   Although this is the desired goal through standardization, it is not currently achievable.

11. Reusable containers should be RFID tagged in the following way:

a. **Use passive read-only RFID tags for reusable containers that will only contain one type of hardware (a specialized container).** This tagging can help locate the containers across the logistics chain, thus reducing damage to critical equipment that must be packaged in specific containers.

b. **Use passive read-write tags for containers that have instructions associated with them for handling, manufacturing of contents, or for cleaning.**

c. **Use passive read-write tags for containers that will have their contents associated with the tag.** Some containers have their contents directly associated with the tags; others have their contents associated with a centralized database that can be updated. For containers that will have their contents associated with them, use passive read-write tags to modify contents as it changes during transit.

12. Anticipate multiple tagging of items and modified pallet handling. Tests have shown that multiple RFID tags on a single item improve read efficiency and accuracy. In addition, placement of RFID tags may differ from traditional line of site bar codes. Norfolk has discovered that pallets must have a more circular shape to improve read efficiency and accuracy. These should be planned into the implementation.

13. Item level, case level and pallet level tracking.

a. **Consider item level RFID tracking for large, complex items with high value.**

b. **Consider case level tracking for groups of relatively high value of items and/or for items that must have additional data associated with them (temperature, time, humidity or other factors that might degrade performance).** This might include perishables and medical supplies, as well as equipment that are sensitive to heat or humidity.

c. **Consider case level tracking for multi-content shipments that will need to be distributed (broken up) during transit at multiple staging areas.**

d. **Consider pallet level tracking for relatively low value items that can be shipped in bulk or that will not need to be broken down multiple times during transit at multiple staging areas.**

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[3] Mark Wutka, Special Edition, *Using Java™ Server Pages and Servlets*, Que, 2000.

[4] Budi Kurniawan, *Java for the Web with Servlets, JSP, and EJB: A Developer's Guide to J2EE Solutions*, New Riders Publishing, 2002.

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[10] Java Messaging Server, http://java.sun.com/products/jms/

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10 Appendices

10.1 Wireless Application for Supply Chain Management

10.1.1. Executive Summary

Both commercial and military logistics applications seek total asset visibility. The emphasis placed on these differs for the two, however, and it is these differences that make direct transplant from commercial applications to military applications problematic.

Thus the value of this report is not necessarily to find direct correlations between the USMC OA and commercial systems that can be directly translated from the commercial sector to a military application. Rather, its benefit lies in the description of the breadth of issues related to wireless and RFID system implementation and the description of commercial uses to date.

The breadth of systems available and in use in commercial logistics activities spans a wide variety of applications. These are detailed in this report and a summary of them appears in Table 10. From an asset visibility perspective, wirelessly enabled scanners combined with bar codes or RFID tags and readers are needed. Either of these two approaches must be tied to a centralized database to link the limited information that can be accommodated on the bar code or RFID tag with additional information about the contents of the item, case or pallet.

The following recommendations are divided into four categories: (1) Communications; (2) Use of bar codes and RFID; (3) Operational changes; and (4) Implementation issues.

COMMUNICATION RECOMMENDATIONS

1. Plan redundancy of communication channels into system, particularly those channels that link into centralized data. Communication linkages must have redundancy built into them, particularly if they are to be effective in non-garrison environments, so that critical item identification and tracking is not lost with communication disruptions. It should be noted that loss of communication is a problem that has been noted as causing difficulties in the implementation of wireless and/or RFID systems. When communication links are down, there is little that the operator or inspector can do to identify the package or item. This further reduces visibility in the supply chain. Though communication disruptions are not as common in fixed locations that share wireless and hardwired channels, in a fully mobile environment this will be a key issue.

2.   Only adopt wireless applications where mobility is essential. Though every aspect of a logistics chain can be wirelessly enabled, some of these nodes do not benefit from wireless, or are too remote to be able to effectively link into centralized systems to fully utilize information. In addition, in the USMC theatre environment, potential targeting of wireless transmissions must be balanced against possible benefits to wireless communication.

USE OF BAR CODES AND RFID RECOMMENDATIONS

3.   Use bar codes for the following:

      a.   Items that can easily be scanned manually.

      b.   Items that must be scanned manually due to some material or other consideration.

4.   Use read-only passive RFID for the following:

      a.   Items that will never change their contents and which do not need to have additional information associated with them during transit. These should be used for items that can easily be scanned by an RFID reader in a fixed location.

      b.   Use read-only passive RFID tags to track critical equipment within a fixed location (such as medical equipment being tracked within a hospital location or key maintenance equipment that might be shared among workers).

5.   Use read/write passive RFID tags for the following items:

      a.   Items that will not change their contents, but which may have additional temperature, time or other tracking recorded during transit.

      b.   Items whose contents may change during transit. This might include pallets whose contents may need to be modified as items are removed and delivered in transit.

6.   The trade-off between fixed location and mobile (hand-held) RFID readers

      a.   Use fixed location readers whenever accuracy is needed (with little or no manual backup)

b. **Use mobile (hand-held) RFID reader when mobile scanning is essential and when procedures are put into place to verify the reads in some way.** Hand held devices are much less reliable (as much as a 78% read accuracy compared to 99% read accuracy of fixed location readers). The use of mobile devices must be carefully considered.

c. **Use mobile (hand-held) bar code scanner when contents of bins or other larger containers needs to be tracked; consider voice activated pick-and-pull inventory for complex combinations of smaller items, or in environments where hands-free is important.**

7. **Carefully match item content, material composition, RFID tag protocol and reader hardware to ensure compatibility.** Some items that will be tracked, as well as their packaging, will interfere or distort RFID signals, thus reducing read efficiency (time to read) and accuracy (correct content). Pilot trials have determined that tags and readers are not interchangeable. Although this is the desired goal through standardization, it is not currently achievable.

8. **Reusable containers should be RFID tagged in the following way:**

a. **Use passive read-only RFID tags for reusable containers that will only contain one type of hardware (a specialized container).** This tagging can help locate the containers across the logistics chain, thus reducing damage to critical equipment that must be packaged in specific containers.

b. **Use passive read-write tags for containers that have instructions associated with them for handling, manufacturing of contents, or for cleaning.**

c. **Use passive read-write tags for containers that will have their contents associated with the tag.** Some containers have their contents directly associated with the tags; others have their contents associated with a centralized database that can be updated. For containers that will have their contents associated with them, use passive read-write tags to modify contents as it changes during transit.

9. **Anticipate multiple tagging of items and modified pallet handling.** Tests have shown that multiple RFID tags on a single item improve read efficiency and accuracy. In addition, placement of RFID tags may differ from traditional line of site bar codes. Norfolk has discovered that pallets must have a more circular shape to improve read efficiency and accuracy. These should be planned into the implementation.

10.   Item level, case level and pallet level tracking.

   a.   Consider item level RFID tracking for large, complex items with high value.

   b.   Consider case level tracking for groups of relatively high value of items and/or for items that must have additional data associated with them (temperature, time, humidity or other factors that might degrade performance). This might include perishables and medical supplies, as well as equipment that are sensitive to heat or humidity.

   c.   Consider case level tracking for multi-content shipments that will need to be distributed (broken up) during transit at multiple staging areas.

   d.   Consider pallet level tracking for relatively low value items that can be shipped in bulk or that will not need to be broken down multiple times during transit at multiple staging areas.

OPERATIONAL CHANGE RECOMMENDATIONS:

11.   Semi-passive tags must be carefully deployed. Semi-passive tags are battery assisted to improve read-range. However, batteries degrade in severe heat and so these tags introduce additional monitoring needs into any system to make sure that the batteries are in working order. The read-range boost must be considered in light of this additional monitoring.

12.   ERP system linkages will require web-based service oriented architecture. The commercial system is going away from monolithic software solutions to modular solutions connected together with web services. Any USMC configuration should plan for this emerging flexibility.

IMPLEMENTATION ISSUE RECOMMENDATIONS:

13.   Anticipate some human-in-the-system interaction for any RFID system (at least in the near to mid-term). Early pilots, particularly at Norfolk Ocean Terminal suggest that human intervention will be needed to verify and validate RFID reads. Though RFID reduces time to read, accuracy must be checked, sometimes manually.

14.   Anticipate possible monitoring of RFID exposure for personnel working with the systems. Though RFID has not been proven clinically hazardous to human health through exposure, this issue continues to concern

workers associated with the systems. Workers at Norfolk, for example, questioned the safety of working within these environments.

15.   Anticipate communication channel changes with the introduction of wireless systems (beyond those built into the system). Experience shows that systems co evolve. With the introduction of any wireless or RFID system, workers will begin to modify their former behaviors and to build new informal communication channels. Unfortunately, the wireless or RFID systems are frequently built on the workflow processes in place or anticipated. Systems such as these change the way that information flows, particularly its direct flow to lower levels in the organization. Workers at these lower levels, now informed, are apt to take on more decision-making activities. This may be in direct conflict with traditional command and control structures of the military.

16.   Anticipate significant investments in middleware software for full system functionality. Currently ERP systems and middleware offer solutions to data exchange and transfer, but commercial experience shows that these linkages are often not robust enough and thus, further investments in customization of software have been required. Careful discussions with vendors will help identify tracking needs and customization required.

17.   Anticipate a difference between garrison activities and in-theatre activities with respect to RFID and bar code uses. Current hand held readers are not as robust and procedures that work for fixed location readers (in garrison) will not necessarily work equally as well in the field with hand held readers. Some human in the system intervention or additional checking/monitoring of ID reads will be required in the field with hand held readers.

18.   Consider use of RFID/bar code printers. To facilitate multiple types of reads throughout the supply chain, printers that generate a single bar code label with an embedded RFID code might be a practical solution to relabeling in transit.

19.   For combined communications on a single platform, a closer look at the Itronix system developed for Sears and others for remote maintenance that has been adapted for use in theatre in Iraq currently by DoD is advised. Before creating a unique system, the USMC should review the current Itronix system in Iraq for possible use in logistics and communication. This system has been developed from a commercial application platform, but with robust features added to address the harsh operating conditions in the field. Though the Sears system and other commercial applications are using the Itronix system for real time maintenance workforce scheduling, the configuration might prove useful to USMC needs.

20.   Develop an RFID tag deployment plan before implementation. Some vendors offer RFID 'boot camp' to help planners anticipate needs and uses; others offer starter kits to help planners develop pilot implementations.

Regardless of the start path, thought should be given to the roll out of RFID since it will have implication for the middleware needed at particular stages, the trouble shooting to anticipate, the robustness of the redundant communication channels and software, and the human-in-the-system needs. If all is not in place prior to rollout, system performance will be degraded if commercial implementations are any guide.

These recommendations are intentionally generic since USMC is currently in the process of choosing an ERP system, and must also comply with DoD recommendations for RFID implementation. Both of these factors will drive optimal RIFD or other wireless solutions, as will bandwidth considerations, particularly in theatre.

10.1.2. Introduction-Report Focus

This report has been prepared as part of the Penn State study for the US Marine Corps to Wirelessly Enable the Logistics Chain. It includes information gained through published sources, presentations at the 2004 DOD RFID Summit held in April 2004 in Washington, DC, and interviews with industry experts from companies including Itronix, Manhattan Associates, ES3, webMethods, Avery Dennison, WhereNet, MeadWestvaco, Printronix, and Bear Stearns.

This report begins with the concept of a service-oriented enterprise and what this means for software architectures and interoperability. It then focuses on wireless technology, particularly radio frequency identification (RFID) systems, and highlights ways that RFID is being used in commercial supply chains to foster asset visibility and efficiencies. The report concludes with implementation issues and recommendations for future USMC activities related to wireless implementations based on analogous activities in the commercial sector.

10.1.2.1. Comparing Commercial and Military Logistics Systems

From a logistics perspective there are key differences between commercial goals and military goals. For the military, key goals include availability and uptime of weapons systems based on performance based logistics. This must include understanding performance of individual pieces of equipment, developing the predictors of performance and initiating condition-based maintenance. Wireless technologies can help in the data collection and reporting. In addition, designing for maintenance and maintenance excellence will be key aspects of any wirelessly enabled logistics chain.

The commercial sector, on the other hand, has been focusing on material handling issues, including inventory tracking and reduction. These identification and tracking issues are also valuable to the military. In addition, the military will

need to authenticate items, ensuring that the item contained is what it claims to be and has not been tampered with.

Thus the value of this report is not necessarily to find direct correlations between the USMC Operating Architecture and commercial systems that can be directly transplanted from the commercial sector to a military application. Rather, its benefit lies in the description of the breadth of issues related to wireless and RFID system implementation and the description of commercial uses to date.

10.1.2.2. The Service-Oriented Architecture of the Future

The OA proposed by the USMC will require a service-oriented architecture (SOA) to leverage information technology systems and to provide wide visibility of assets by using multiple communication platforms. A service-oriented architecture is an approach to software design that includes reusable components (modules) like building blocks. In the SOA framework, the building blocks are known as "services," where each service performs a distinct function. For the building blocks to work together, careful attention must be paid to the interfaces that loosely couple these services. Loose coupling offers maximum flexibility. Gartner Research predicts that by 2008, SOA will be the prevailing software engineering practice (with a 0.7 probability); this SOA will replace current monolithic software architectures. Experts expect SOA to be implemented in web-based formats linking multiple platforms, legacy systems, and databases in real-time through dynamic interfaces.[1]

Not only will systems be talking to each other, but so will machines. Machine-to-machine (M2M) communications are expected to grow dramatically in the coming five years, and some experts predict that M2M will drive $180 billion dollar annual business by 2008 compared to only about $34 billion today.[2] What makes this interesting is that wireless phone companies are looking at this opportunity as a way to further use cellular networks, competing with and complementing internet companies. The key technical challenge will be tying all multiple device inputs into legacy data and information systems. At the present time, M2M communications enabled wirelessly are growing most rapidly in Europe, partly driven by France Telecom's mobile subsidiary, Orange.

SOAs and M2M communication introduce complexity into what today are relatively stable information systems. *Businessweek*[3] sums up the future potential as follows,

"In the end, companies likely will harness a mix of wireless systems. Packages in the back of a truck might talk to the driver using a ZigBee network, sending a

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[1] webMethods White Paper, *Blueprint for the Service-Oriented Enterprise*, March 2004.

[2] Reinhardt, Andy. "A machine-to-machine 'Internet of things'," *Businesweek*, special report, April 26, 2004.

[3] Ibid.

warning if something tips over and breaks. At the loading dock, signals could be gathered and sent to tracking systems via Wi-Fi. On the road, the data would phone home over cellular networks…[forming] a mix of local and remote communications, all seamlessly linked together."   (April 26, 2004)

The current report focuses on asset tracking and visibility, particularly RFID systems.   This is only one part of the total wireless logistics-related communications, but it is the portion of the system that is most well documented and formed in the commercial sector to date and offers insight into the complexities of evolving IT systems and organizational systems. For the USMC, anticipating the co evolution of wireless systems and current command-and-control communication and decision making patterns will be essential during system implementation.

10.1.3. Introduction to Wireless Applications

Emerging technology solutions will introduce several disruptions to current supply chain activities. Within factories, networked computing is being replaced with wireless communications.   FedEx estimates its Wi-Fi-enabled workers are 30% more productive compared to their counterparts. Today 57% of all U.S. corporations, including all of the FORTUNE 1000, have at least a small-scale Wi-Fi network, although only a few tech-savvy firms like Qualcomm and Novell have so far dared to roll out wireless service company-wide.[4]

Inventory tracking, even during production, is transitioning from bar coding to RFID tags.   Between factories and with customers, internet-supported communication and tracking is replacing paper and verbal communication patterns. New developments in sensors (microelectromechanical systems) and miniaturization will dramatically increase connectivity.

Today, we think about connectivity as a network. New technologies will change connectivity to a commodity – everything will be connected to everything else in some way. The challenge is twofold: (1) envision operations as they might look in 2010 and beyond; and (2) determine how best to navigate the transition from current patterns to ubiquitous computing and communications. An underlying requirement to fully establish connectivity is the development of standards and protocols for the software interfaces and hardware configurations.   RFID is still in its infancy in the context of supply chain applications and vendors; potential users and governments around the world are struggling with the issue of standards.

The USMC, in seeking to rationalize its supply chain, has begun the process. Sweeping changes enabled by technology will require changes to organizational structures and reporting requirements. In addition, the USMC must consider not only current off-the-shelf approaches, but also potential future developments.

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[4] Taylor, Chris, "Will you buy Wi-Fi?" *Time*, April 21, 2003. www.time.com

Finally, the USMC must also link its decision making to broader DoD initiatives and directives regarding the use of RFID. The overarching goal is to improve asset visibility.

10.1.3.1. Emerging Wireless Technologies

There is an evolving standard, 802.16 for mobile area networks.[5] It is currently being developed by the IEEE 802.16 Working Group as a standard for broadband wireless access that offers high speed/capacity, low cost, and a scalable solution to extend fiber optic backbones. The standard, published in April 2002, defines the WirelessMAN Air Interface. 802.16 support point-to-multipoint architectures in the 10-66GHz ranges, transmitting data rates up to 120Mbps. A base station connects to a wired backbone and can transmit wirelessly up to 30 miles to a large number of stationary subscriber stations. Some believe that the WLAN, operating like a hub or bridge, will add security to wireless networks through a series of switches. A series of access points provides user authentication and facilitates roaming between access points and subnets.[6] For a simplified description of wireless infrastructures, the reader is referred to CNET's Guide to Going Wireless.[7]

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[5] Geier, Jim, "802.16: A future option for wireless MANs," Wi-Fi Planet, July 17, 2003

[6] Vance, Jeff, "Switch or Gateway: Future-proofing your Wi-Fi Network," August 26, 2003

[7] CNET's Guide to Going Wireless, May 30, 2004.
http://asia.cnet.com/reviews/hardware/networking/0,39001739,39150884,00.htm

Table 1: Key wireless technologies used in computers, mobile phones and other devices[8]

	Purpose	Frequency	Range	Speed	Devices	Compatibility
802.11a	Wireless internet access	5 GHz	25 to75 feet indoors; range can be affected by building materials	Up to 54 Mpbs	Laptop computers, PDAs, cell phones	Not compatible with 802.11b, 802.11g
802.11b (Wi-Fi)	Wireless internet access	2.4 GHz	Up to 150 feet indoors; range can be affected by building materials	Up to 11 Mbps	Laptop computers, PDAs, cell phones	Other 2.4 GHz devices like cordless phones may disrupt connection
802.11g	Wireless internet access	2.4 GHz	Up to 150 feet indoors; range can be affected by building materials	Up to 54 Mbps	Laptop computers	Other 2.4 GHz devices like cordless phones may disrupt connection
Bluetooth	Wirelessly connect computer peripherals, such as printers, PDAs, cameras	2.4 GHz	Up to 33 feet (10 meters); range can be affected by building materials	720 Kbps	Printers, cameras, cell phones, PDAs, other peripherals	Other 2.4GHz devices like cordless phones may disrupt connection
GSM (Global System for Mobile Communications)	Digital cellular telephone system; most-used system world wide	900 MHz, 1,800 MHz, 1,900 MHz	Determined by host network	Determined by host network	GSM enabled cell phones, PDAs, pagers	Not compatible with CDMA, TDMA networks
3GSM	Third generation GSM network	1,920-1980 MHz and 2,110-2,170 MHz	Determined by host network	2 Mbps data rate	3GMS-enabled cell phones, PDAs, pagers	Not compatible with CDMA networks
GPRS (General packet Radio Service)	An interface overlaid on existing GSM networks to allow for user internet access	Determined by host network	Determined by host network	Theoretical maximum speed of 171 Kbps; reality is 40-50 Kbps	GPRS-enabled cellular phones and networks	Does not support CDMA networks

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[8] CNN.com Special Reports, October 16, 2003.

Continued Table 1: Key wireless technologies used in computers, mobile phones and other devices[9]

	Purpose	Frequency	Range	Speed	Devices	Compatibility
CDMA (Code Division Multiple Access)	Digital telephone system used mainly by U.S. cellular networks	800 MHz, 900 MHz, 1,700 MHz, 1,800 MHz, 1,900 MHz	Coverage area of host network	14.4 Kbps data rate; a revised CDMA standard offers 64 Kbps	Mobile phones on CDMA networks	Not compatible with GSM, TEMA networks
CDMA2000	Third generation CDMA-based network	Any existing band	Coverage area of host network	144 Kbps; future speeds are estimated as high as 4.8 Mbps	Mobile phones on CDMA2000 networks	Not compatible with GSM, TDMA networks
CDPD (Cellular Digital Packet Data)	System used to transmit data over analog cellular networks	800 MHz, 1,900 MHz	Coverage area of host network	19.2 Kbps data rate	Cellular phones, PDAs, pagers	N/A
TDMA (time Division Multiple Access)	Digital cellular telephone systems	800 MHz, 1,900 MHz	Coverage area of host network	74 Kbps to 120 Mbps data rates	TDMA cellular phones	Not compatible with GSM, CDMA networks

10.1.3.2. Tracking Equipment Mortality

Equipment does not fail at the same rate over time. Wireless monitoring of new or newly overhauled equipment is gaining popularity. According to SKF Reliability Systems of San Diego, CA, infant mortality in new equipment is nearly 72% of industrially installed equipment.[10] If this equipment could be monitored in its early use, problems could be identified and corrected faster. Using wireless technologies enables a rapid redeployment of monitoring equipment once the new piece of equipment is confirmed in working order.   This creates a time-efficient troubleshooting and maintenance strategy.

Michelin has begun a pilot program where RFID tags are embedded into tires to track possibly faulty tires. The program is in response to Congressional law mandating that tire makers more closely track tire performance.[11]   Other tire companies are expected to follow.

10.1.3.3. Wireless Maintenance & Workforce Scheduling

Effective field-maintenance capabilities are essential to continuous operations and to customer service. Field maintenance has been supported by wireless

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[9] CNN.com Special Reports, October 16, 2003.

[10] Teresko, John, "Winning with wireless," *Industry Week*, June 2003, p. 60-66.

[11] "Embedding RFID tags in tires," *DigitalEarth.org*, January 22, 2003.

cellular technology available commercially; private specialized mobile radio networks for companies in compact geographic locations; and satellite communications for companies whose workers are located in areas not served by normal cellular coverage or by public packet-switched networks.[12]

Sears has equipped the trucks used by more than 11,000 service technicians with GPS 802.11 wireless LAN and packet data services supported by a five-antenna dome located on the trucks. The configuration is detailed in Figure 1. The five-antenna configuration includes:

- An 802.11b wireless local area network
- One antenna for traditional terrestrial packet data network, such as Mobiltext
- One antenna for a more expensive satellite packet network;
- An antenna dedicated to feeding the GPS signal to mapping software on technician laptops; and
- An antenna that uses a back feed channel on the GPS signal that will pass it to a transceiver in a small device on the technician's keychain. This is intended to pinpoint the technician's location.

Two companies, Itronix and Wireless Matrix, designed the system. With these wireless networks, technicians have better access to data. Matt Gerber of Itronix describes the system as a wireless mobile computing platform to manage the scheduling of Sears' maintenance workforce. [13] The system was installed in 1997-98 and paid for itself in the first year of operation through increased efficiencies in workforce scheduling and increased customer satisfaction. Now in its second-generation form at Sears, the system continues to reap benefits for the company.

All calls for the Sears solution come in to a centralized call center where unscheduled work (customer requested) is integrated with scheduled maintenance using a system that also takes into account the technician's skill set. The automated dispatching system distributes daily job lists to technicians that the technician can access either through the company Ethernet network in the office or via wireless access.

The technician downloads data about the day's route and job schedule; for larger bulk downloads of technical service information, Sears uses CDs to share information. Currently, the bandwidth required for sharing of technical service data and schematics exceeds system configurations and bandwidth limitations.

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[12] One of the leading providers of packet-switched networks is Woodbridge, N.J. based RAM Mobile Data USA. Commercial satellite service in North America is commercially available through American Mobile Satellite Corporation in Reston, vA.

[13] Matt Gerber, Vice President of Marketing and Business Development, Itronix. Personal conversation, May 18, 2004.

The wireless software architecture is smart enough to determine what type of communication channel is most effective (and available) for the terrestrial LAN and the satellite network.

Matt Gerber noted that wireless workforce management systems such as this are used in the oil and gas industry, and by clients such as Honeywell, for their maintenance real-time work management. He also noted that a similar system is being used in Iraq for battlefield situational awareness. This environment is particularly challenging and redundancies have been built into the system including:

- Spare parts of the battlefield for key computer and system components
- Removable hard drives for the computers so that systems are not down due to hard drive failure
- Redundant communication mechanisms

Additional redundancies need to be considered for the linkages to the mainframe databases.
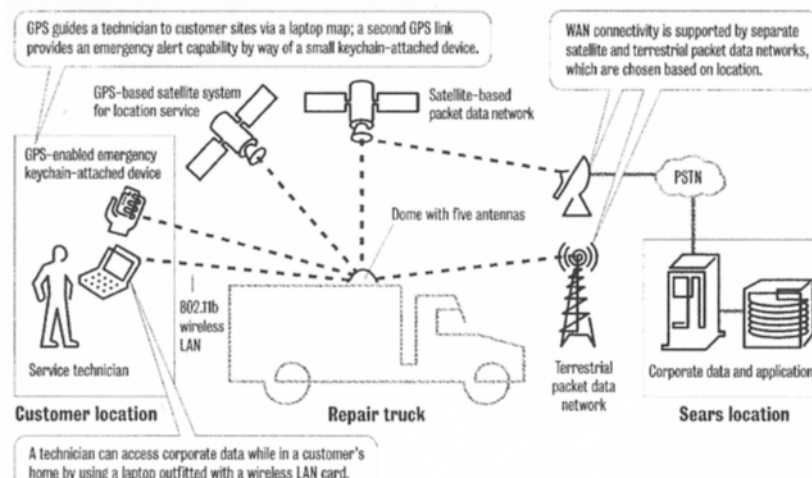
Figure 1: Sears boosts employee productivity through access to multiple wireless networks enabled by a five-antenna dome situated on service technicians' trucks.[14]

Finally Mr. Gerber indicated that his company has a parallel project ongoing with General Dynamics to develop smaller, more efficient fuel cells to further improve the system's ability to meet wireless needs on the battlefield.

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[14] Cox, John, "Sears techs packing a wireless punch," *NewtorkWorldFusion,* October 1, 2003.

10.1.3.4. Managing Shipments

Some wireless applications can increase supply chain visibility using traditional cell-phone or other technology. ABF Freight, a $1 billion motor carrier, is using Nextel's wireless technology to improve productivity and customer responsiveness. Nextel's micro browsers are essentially cell phones with open connections to the Internet, a very cost effective technology.[15] ABF has been able to leverage a mass-produced cell phone for about $80 each and the cost continues to decline each year. About 40% of the company's drivers are using these cell phones in approximately 52 terminals and in dock and yard operations in all nine of ABF's distribution centers. In fact, ABF is using wireless technology to manage three areas: street, dock, and yard. It is doing this by using the phone's keypad to enter important information that is directly uploaded into ABF's mainframe. By linking this information to ABF's website, customers can see within minutes when a shipment is delivered. Micro browsers are also facilitating tracking of shipments in the dock and in the yard, identifying where workers should put specific inventory.

Nextel actually has a continuum of wireless solutions that vary according to user needs. At it's simplest, cell phones allow for two-way communications between the head office (centralized data storage) and the driver (remote data entry point). Walkie-talkie types of communications are the next step up the continuum, followed by two-way messaging facilitated by the Internet through a hand-held device using a text-messaging format. Nextel also has a partnership agreement with @Road, a provider of fleet management solutions that uses an in-vehicle GPS unit.[16]

10.1.3.5. Wireless Needs of the Future Warfighter

The 325th Airborne Regiment at Fort Bragg has already piloted mobile medical records in conjunction with the Telemedicine & Advanced Technology Research Center (TATRC) at Fort Detrick, in Frederick, MD.[17] Under this pilot project, each soldier in the unit was issued a digitized medical record on a card about the size of the traditional dog tag. All of the 325th deployed to Iraq were provided with a secure hardware-independent flash memory card. Brigade medics were provided with hand helds to read and write to the memory card, as medical treatment was needed. Future developments to make this system more robust include voice recognition systems and natural language processing.

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[15] Hyland, Tricia, "Advancements in wireless capture attention," *Transportation & Distribution*, February 2002, p. 20-25.
[16] Hyland, Tricia, "Advancements in wireless capture attention," *Transportation & Distribution*, February 2002, p. 20-25.
[17] Prencipe, Loretta W. "Supply chain and logistics," *InfoWorld*, June 2, 2003, p. 52

WARRIOR OF THE FUTURE

Innovations that could show up on the battlefield during the next decade

ALL-SEEING SENSORS
Radar, night vision, and video cameras would probe behind walls and into the dark—and relay images to commanders

SUSTENANCE PACK
Air filtration system and drinking tube would enable soldiers to fight when under biochemical attack

BODY ARMOR
A cloth-like material would allow more flexibility than the current armor plates

ARTIFICIAL MUSCLE
External bone-and-muscle system would extend endurance and provide extra strength

DISPLAY
Built into the visor, it would show text messages, map coordinates, and other tactical info

BIO SENSORS
Next to the skin, they would track vital signs and relay data to medics

'SMART' FABRIC
Would sense and then seal out chemical or biological weapons, eliminating the need for a separate biowarfare suit

Figure 2: Future War fighter

Looking at U.S. Army plans to equip its "Future Warrior," (See Figure 2) offers suggestions about how the warfighter of the future may require or benefit from wireless technology and communications.[18] Much of this combat gear is being designed under classified projects with DuPont, EIC Laboratories, Inc., and at MIT's Institute for Soldier Nanotechnologies.

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[18] Port, Otis "Super Soldiers." *Business Week,* July 28, 2003, p 62-64.

From a wireless point of view, many of the proposed developments that include sensing the soldier's health, location, and needs might effectively be supported by wireless technology.

In such a deployed environment, the tradeoff will be between immediate notification of health status or changing needs with the ability of enemy forces to target the warfighter through such a transmission. Interesting to note, the advances in body armor will reduce the weight that soldiers carry into battle. This may facilitate wireless communication, as soldiers will need to tote batteries of varying sizes and weights, depending on their destinations.   The U.S. Army plans to fund nearly $25Billion worth of research aimed at developing new ways to generate and store power. With today's technology, a typical brigade of 1,500 troops goes through 120 tons of batteries in a year – and that is with current technology needs. Super Soldier and wireless applications will increase power needs dramatically. This may well become a limiting factor to the deployment of wireless technology in the battlefield.

10.1.4. Creating Asset Visibility

10.1.4.1. Inventory ID and Tracking

Inventory ID is really about creating product integrity, which is captured by three separate aspects:

Authentication – is the item, pallet and/or case actually what the label claims? Has it been tampered with in any way?
Tracking – is the item, pallet and/or case located in an area where it is needed and is its quality still within usable limits?
Tracing – where has this item been (daisy-chain tracking)?

A unique identification number enables the synchronization of financial flows, information flows and physical flows. The three elements above guarantee that the physical flows can be verified and that the usability of the product can be safely ensured.[19]

Automatic identification and data collection (AIDC) applications use bar codes, radio frequency identification, magnetic strip, voice and machine vision systems, optical character recognition, and biometrics methods to identify and track inventory. By far, the most pervasive is bar coding.

For the past 25 years, bar codes have been the most common method used to track inventory. Bar codes are a line-of-sight technology that enables scanners to identify the product type when the code is oriented toward the scanner.   The

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[19] Daniel Engels (Research Director, MIT Auto-ID Labs), "RFID in the business process," DOD RFID Summit, April 2004

success of bar code labels depends on the label's readability and its adhesion to the product.[20] For bar code labels made of paper, there are three critical factors to consider: temperature of the tagged item, the environmental temperature, and the label's intended use. Plastics challenge many currently available adhesives for paper labels. The ink used in bar codes also affects reliability, with some inks particularly susceptible to sunlight (or fluorescent light).

In addition to paper bar code labels, they can also be made from ceramic, metals, embossed rubber tags and direct part marking. Ceramic labels work best in high temperature applications. More recently, on-demand thermal transfer systems have been used to produce crisp bar codes on custom-cut labels that withstand moisture, humidity, tear resistance, and high-pressure sprays and abrasion.

For applications that require lifetime part traceability, direct part marking is often used. General Motors, Boeing, NASA and others use this indented bar code to permanently mark their parts. Bar codes that are etched or dot-peened onto an item can only be read by an imaging (camera-based) scanner. This generally adds to the cost of such a system. Parts can also be direct marked by ink-jet or laser printing technology that can be read by traditional laser scanners.

More recently 2 dimensional bar codes have gained a foothold in inventory tracking, helping to link items to cases. Experts expect that in the future, inventory systems will have to accommodate a hybrid system of 1-d and 2-d bar codes as well as RFID.

Several devices support inventory tracking, including voice recognition systems, wearable devices, tablet computers and rugged PDA's. Standardization is increasing interoperability of devices. 802.11 and its derivatives are the standard developed by the Wireless Ethernet Compatibility Alliance, WECA. The shift to wireless for warehouse management is moving to the use of cell phones and PDAs via Internet access on either a real time or batch mode.

10.1.4.2. DoD RFID Goals

In October 2003, the U.S. Department of Defense announced its Radio Frequency Identification Policy. RFID technology greatly improves the management of inventory by providing hands-off processing. The equipment quickly accounts for and identifies massive inventories, enhancing the processing of materiel transactions. In addition to reducing supply chain management and tracking needs, RFID will enable DoD to improve business functions and facilitate all aspects of the DoD supply chain.   However, the reality of RFID implementations falls short of the theoretical possibilities.
The new policy will require suppliers to put passive RFID tags on the lowest possible piece part/case/pallet packaging by January 2005. Acknowledging the impact on DoD suppliers, the DoD has hosted summits for industry vendors and

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[20] Albright, Brian, "Extreme environments," *Frontline Solutions,* February 2003, p. 16-21.

its suppliers; this report includes information from the most recent April 2004 RFID Summit. The RFID policy and implementation strategy will be finalized by June 2004.   The RFID policy and the corresponding RFID tagging/labeling of DoD materiel are applicable to all items except bulk commodities such as sand, gravel or liquids.[21]   The DoD goal is total asset visibility, with a desire to link the "foxhole to the supplier factory floor" for critical items.[22]

Mr. Ed Coyle, Chief, DoD Logistics AIT Office, DLA, stressed the importance of the warfighter in its planning for possible RFID implementations. In the readiness, sustainment, closure and reset cycle of U.S. force deployments, Coyle noted the new challenges of rapidly moving a force on a dynamic battlefield, and the need for better information on in-transit assets and underlying demands for more effective management of inventory. This requires better real-time information.

The DoD RFID Summits for Industry are a way for the military to share its goals with its suppliers and with RFID software and hardware vendors.   Some key issues surrounding RFID implementation include

- Identification of items to be tagged – current DoD thinking is that all items in excess of $5,000 and/or which have a DoD unique identifier will need to be RFID enabled.
- Identification of the level of tracking desired – in transit visibility must be rationalized at the individual item, case, and pallet and container level.
- Use of DoD Unique Identifier (UID) or the Electronic Product Code (EPC) identifier – currently the UID number is longer than that which can be accommodated in the EPC identifier. DoD and the EPCglobal, the international id agency, are discussing ways to accommodate this discrepancy.
- Linkage of UID or EPC to inventory systems through AIS systems – tracking can only be facilitated if the id numbers are transmitted to the current inventory support systems.
- Linking UID or EPC to Advance Shipping Notices (ASN) to improve knowledge of incoming inventories (and to increase efficiency of payments to suppliers).
- Preferred use of passive RFID tags to track inventory and asset visibility. Current DoD use of active tags such as those produced by SAVI for container tracking is not envisioned at the item-level or case-level. There are some opportunities for active tags at the pallet level, but this is not the current DoD preferred option.
- Use of read-only or read/write tags – the complexity and longevity of tags must be evaluated to determine the best solution on an item-level or larger basis.
- Worldwide RFID enabled visibility and the Status of Forces Agreements that require reporting.

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[21] http://www.dod.mil/releases/2003/nr20031023-0568.html
[22] Mike Wayne, Acting Under Secretary of Defense, Acquisition, Technology and Logistics, Opening Keynote, 2004 DOD RFID Summit for Industry, April 6-8, 2004.

Presently, the DoD estimates that there are over 4.5 million stock units of volume needing to be tracked. The emphasis will be on enterprise integration and expanded end-to-end policies. Using RFID technology, the military hopes to achieve reliable delivery, weapons systems support, performance based logistics, and information about available weapons systems. The military hopes to design out logistics complexity and to reduce the cost associated with identification, authentication and tracking. The hope is to also reduce the current logistics footprint. In return for supplier cooperation, and related to the e-government initiative, suppliers will benefit through rapid payments on tagged items received and transferred to inventory via RFID technologies.

DoD officials also see a benefit using RFID technologies to increase interoperability between international forces. Using common codes (anticipated being a blended version of UID and EPCglobal codes), RFID technology should be able to help rationalize inventories between forces deployed to common regions. This will require standardization across military platforms, and commonality across international forces, a longer-term goal.

10.1.5. The RFID System

In the Auto-ID system, a combination of tags, antennas, readers, and local computers ('Savants') provides a near real-time view of product status and location. The key components of the Auto-ID standard are: Electronic Product Code (EPC), RFID tags, Tag readers, Savant servers, Object Name Service (ONS), and the Physical Markup Language (PML). The EPC identifies individual products, but useful information about the product is written in a new, standard computer language called Physical Markup Language (PML). PML is based on the widely accepted, extensible markup language (XML), and is expected to become a universal standard for describing physical objects, processes, and environments.[23] An RFID system includes RFID tags, antennas, a reader, RFID middleware (to process incoming RFID signals), and supply chain execution (SCE) software. See Figure 3.

Figure 3: The RFID system[24]

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[23] Sun Microsystems White paper: Sun and Auto-ID.   Sun Microsystems White Paper: Sun and Auto-ID. September 9, 2003. 32 pages.
[24] Manhattan Associates 2002 Annual Report, p. 15.

One solution, the Sun™ architecture, is illustrated in Figure 4. This architecture is intended to connect RFID technology (shown at the lower left of the figure) into existing enterprise resource systems (shown at the top of the figure).   This particular architecture is based on open standards.   This, and similar systems, begin with the RFID tag and EPC. The readers detect the EPC data and the data is passed to the Savant which acts as an event manager that filters out extraneous EPC reads or events.
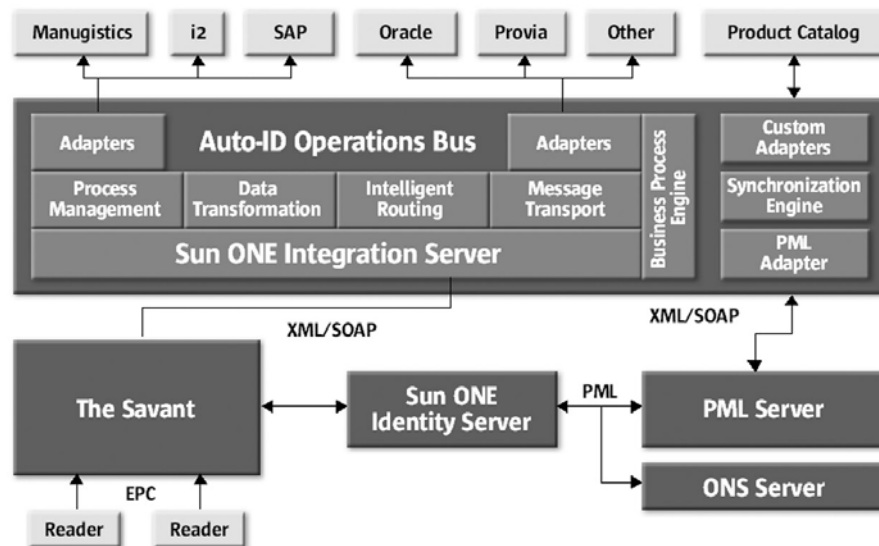
Figure 4: The RFID-enabled Supply Chain Execution Infrastructure Co-developed with Auto-ID Members[25]

The ONS Server provides the IP address of a PML Server that stores information pertinent to the EPC. This is the unique data for each individual piece that is tagged with an RFID.   Data from the Savant is passed into the application infrastructure, or operations bus, either locally or over a WAN such as the Internet. From here, the data is made available to virtually any application that can make use of it.

10.1.5.1. *RFID Tag Technology*

Some commercial warehouse management systems have gone RFID/wireless. The central premise of these systems is the inventory status in a central database is always current since wireless strategies eliminate "information float" – the gap between the time something is inventoried and when the database is

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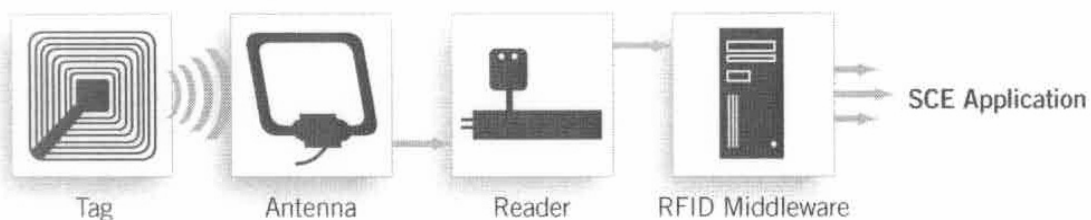[25] Sun Microsystems White paper: Sun and Auto-ID.   Sun Microsystems White Paper: Sun and Auto-ID. September 9, 2003. p9.

updated.[26] RFID application to inventory tracking dates to the 1980s and allows for non-contact reading. RFID is effective for manufacturing and other hostile environments where bar codes would find survival difficult.

A tag consists of an RFID chip and an antenna. There are three types of tags – active, semi passive and passive. Current supply chain inventory management developments are focusing on passive RFID since it is less expensive to manufacture and deploy.[27]

Like bar codes, RFID tags offer automatic data capture. The antenna on the RFID microchip transmits the identification information to a reader that converts the radio waves returned from the tag into a form that can be computer-read. Such systems are not limited by the bar code's more traditional line-of-sight (optical) requirement. The RFID code can be read as long as the tag is within range of the reader. Reader range and antenna strength are two important factors in efficient RFID system performance.

Passive RFID tags draw power from the reader that sends out electromagnetic waves to the tag's antenna. Because of this, passive RFID tags are range limited to within about 10 feet of the reader. Active RFID tags, on the other hand, have a battery which runs the microchip's circuitry and which broadcasts a signal to the reader. Active tags can communicate at distances up to about 100 feet from the reader. Semi-passive RFID tags are a hybrid. They draw power from the reader to communicate, but also use a battery to run the chip's circuitry. Table 2 summarizes their various characteristics.

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[26] Trebilock, Bob, "Mobile computing: It's not just for delivery routes," *Modern Materials Handling,* March 2001, p. 65.

[27] Fowler, John and Heyman, Dirk, "RFID takes stock of supply chain," *Network World,* 6/09/03.

Table 2: RFID Tags and Characteristics[28]

	Active Tag	Semi-Passive Tag	Passive Tag
Power Source	Battery on tag	Battery for chip operations; Radio wave energy from reader for communication	Radio wave energy from reader for operation and communication
Tag Signal Availability	Always on; 100 feet range	Only within field of reader	Only within field of reader; less than 10 foot range
Signal Strength of Tag	High	Low	Very low
Required Signal Strength from Reader	Very low	Low	Very high
Typical Applications	Useful for tracking high-value goods over long ranges. Example: Railway cars on a track		Useful for high-volume goods where items can be read from short range. Example: retail checkout

Passive tags receive their energy from the interrogation source – the reader. The signal from the reader allows the tag to power up. Currently the U.S. uses about 4 watts of power; in Europe about ½ watt is used. The power output is related to tag range. Passive tags tend to have less memory and data rates are slower with passive tags. Because of this, too much data on a tag is not necessarily a good thing with passive tags and the tags must be carefully matched to the application and the complexity of tracking and the speeds needed for the system.

Semi active tags are battery-assisted. There is no transmitter in the tag (as there would be in an active tag), but a battery can boost tag range. Battery life is impacted by temperature, and has a finite life, and so semi active tags must be matched to applications where read range must be boosted, but where the tradeoff is additional complexity of the tag and monitoring of the tag's battery life.

The price range for active tags is approximately $10 - $150 while the price for a passive tag hovers at around $1 each.[29] Though prices approaching 5¢ per passive tag have been touted, these prices are generally associated with very large volume orders, at quantities nearing 1 billion tags. More realistic prices for passive tags range from about 20¢ to about 75¢ per tag, with differences largely depending on durability.   Experts predict that the cost of tags will go down over time, with less cost variability between the lower end and the higher end tags.

Not all RFID tags operate equally, even when operating on the same frequency. Tag performance has been related to its characteristics. The performance of the RFID system is related to the read range of the reader, the tag orientation and

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[28] Sun Microsystems White paper: Sun and Auto-ID. Sun Microsystems White Paper: Sun and Auto-ID. September 9, 2003. p6.

[29] Coyle, Tom. "Material control RFID and the mainstream supply chain," *Material Handling Management*, September 2003, p. 48.

the speed at which the reader must recognize the tag (i.e., moving on a conveyor versus linking to a handheld, versus identifying multiple items in a case or on a pallet compared to identifying a single item at a time). Currently, it is the antenna that appears to be the real differentiator in RFID system and tag performance. Moreover, handheld and mobile readers are far from commercial viability and reliability as compared to their stationary counterparts.

Relationship between tag characteristics and performance[30]

- Tag sensitivity – Sensitivity is defined as the ability of a chip to be energized to provide maximum signal strength back to the reader. The greater the chip sensitivity, the longer the read range;
- Tag size – larger tags generally mean longer ranges;
- Tag shape – different tag antenna shapes provide different levels of performance
- Number of antennas attached to the chip – two dipole antennas attached to a single chip results in tag performance that is less sensitive to orientation, a particularly important feature in random reading environments;
- Speed – Rapid read rates increase the reliability of tag reads and are less likely to impose burdens on business processes. Today, read rates vary for RFID tags from as low as 20 tags/second to more than 1,000 tags/second;
- Tight tag stacking – when stacked closely together, tags may interfere with one another. The best tags available today work effectively even when situated within one-half inch of one another;
- Interference – well-designed tags and readers perform effectively in "noisy" RF environments. Interference in such environments can compromise data integrity;
- Packaging – how tags are packaged and attached to assets influences read range and readability;

Material the tags are attached to – metal and water-based materials are generally hostile to RIFD, negatively affecting read range. Short buffers between the tag and the asset for such materials have proven effective in reducing this problem. Water-based materials, for example, have been found to reduce the collection ranges by as much as 50%. The friendliest materials for RFID tags appear to be cardboard, clothing and plastic.

The chip's protocol defines the communication language, the modulation method, anti-collision techniques, and message formatting. Tags and reader protocols must match for communication to occur. Anti-collision techniques are needed when several hundred tags "send" to a reader simultaneously. The reader and associated software must be able to differentiate between each unique tag.

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[30] Coyle, Tom. "Material control RFID and the mainstream supply chain," *Material Handling Management*, September 2003, p. 49

Some anti-collision algorithms work better with one tag than with another and this is determined in the protocol, which is written into the silicon when the tag is produced. Thus tag / reader combination selections must be determined based on the way that the two will work together in a particular application.

10.1.5.2. Read Problems with RFID Technology

Procter and Gamble, which focuses on pallet and case-level tracking, has broken down its inventory into four classes, depending on the base material:

Paper and hygiene products – easily read with RFID technology available today;
Powdered detergents – increased density and moisture content make 100% readability difficult with current technology;
Liquids – very difficult to read due to density of material and air-space must be managed carefully in regard to tag placement to improve readability; and
Metalized packaging (including foil packaging) – the combination of reduced air space and the foilized packaging is creating difficulty for current tag/reader technologies.

Although P&G hasn't changed packaging yet, it is contemplating packaging changes to accommodate RFID systems. This is a longer-term issue that P&G has yet to address.

10.1.5.3. RFID Tag ID

RFID chips can be read-only or read-write, depending on the application. The tags use Electrically Erasable Programmable Read-Only Memory.   An Electronic Product Code (EPC) identifies the object and all data related to that object is stored on a server on the Internet. The EPC system automatically links the EPC code with the correct database, giving near real-time and highly accurate data about the specific object.

Tags that are read-only must be written at the point of manufacture. This requires that the manufacturing supplier be clear on the customer ontology for its identification codes. Since many tags have a long life, a read only tag may interfere with other tags that get applied later in the logistics chain during repacking and distribution. Read only tags should be used in applications where the item on which it is placed will always need to be identified as such. For example, read-only tags on reusable packaging, which may have different content over time, would not be advised.

Read/write tags are more expensive, but possess greater flexibility and capabilities. Here data on a tag can be changed as the content of the box, case or pallet changes. Currently, however, data is not written in nanoseconds and so tags must be sequentially written one at a time.

10.1.5.3.1.   Auto-ID – Combining Bar Code and RFID

The Auto-ID Center located at MIT, pioneered auto-ID tags and their protocols. The Auto-ID Center hopes to use the electronic product codes (EPC) to transition from bar codes.   The EPC is basically a serial number, with a structure that follows the Global Trade Item Number (GTIN) guidelines.

The EPC has a header and three sets of data: the EPC manager (28 bits), the object class (24 bits) and the serial number (up to 36 bits). See Figure 5.   The EPC manager is most likely the manufacturer of the product; the object class is the type of product, and the serial number is unique to that specific item.   A key difference between EPCs and traditional bar codes is that the EPC provides a unique serial number for every item in the system; whereas the bar codes only identify groups of products. The EPC code is divided into numbers that identify the manufacturer, product, version and serial number. This ties an individual item to its particular manufacturing history.   Additional data may be coupled to this unique EPC identifier through global network software and application-specific middleware.   Such one-of-a-kind EPCs, coupled with RFID tags, will enable complete visibility of individual items within the supply chain. See Figure 6. This will eliminate the need to perform inventory counts and will drastically reduce misshipments.

Figure 5: Electronic Product Code Example. Source: Auto-ID Center Technology Guide.

There is no guarantee that the EPC will be adopted worldwide, but the Uniform Code Council and the EAN International, the two main bodies that currently oversee bar code standards, are supporting it.

More recently EPCglobal has been formed with the goal to become the organization that develops standards for the use of RFID technology. EPCglobal is a joint venture between EAN International and the Uniform Code Council (UCC).   This is a not-for-profit agency that was established in 2003.   The Department of Defense is working closely with EPCglobal to rationalize the emerging EPC code with the existing DOD UID.   Updated information about

EPCglobal and its evolving standards will be available at the EPCglobal conference in Baltimore in September 2004. [31]

The Auto-ID Center has proposed EPCs of 64- and 96 bits. Eventually, there could be more. The 96-bit number balances the desire to ensure that all objects have a unique EPC and the need to keep the cost of the tag down. The 96-bit EPC provides unique identifiers for 268 million companies. Each manufacturer can have 16 million object classes and 68 billion serial numbers in each class, more than enough to cover all products manufactured worldwide for years to come. Since there is no need for that many serial numbers at this time, the Auto-ID Center has proposed an interim 64-bit code. The smaller code will help keep the price of the RFID chips down initially, while providing more than enough unique EPCs for current needs.[32]

Within the DoD, the EPC codes have yet to be established as the standard naming convention. In fact, the DoD is currently in discussions with EPCglobal to try to find a hybrid solution to include either EPCglobal numbers or UID numbers on DoD items for RFID tracking. Policies are expected to emerge in mid-summer for comment by the broader user community.

Technology is evolving that prints a bar code label with an embedded RFID tag. Once associated, this tag is multipurpose and provides both an RFID and a visual identification of the item and/or case/pallet content. These dual labels are being effectively used in shipping.[33]

In the context of ubiquitous ID technology, the unique identifiers assigned to distinguish objects are called ubiquitous IDs, or ucodes. These ucodes are given to a spectrum of objects that make up the ubiquitous computing environment, and they enable the objects to be recognized automatically. The ucodes are conveyed by means of devices called ucode tags, which the Ubiquitous ID Center deals with in different forms: barcodes, RFID tags, smart cards, active chips, and so on. The center classifies tags in 9 classes ranging from class 0 to class 8. (See Table 3)[34]

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[31] EPCglobal conference 2004 will be held September 28-30, 2004 in Baltimore, MD. For additional information visit the EPCglobal website at www.EPCglobalUS.org.
[32] www.autoidcenter.org
[33] Printronix is located in California. www.printronix.com
[34] Ubiquitous ID Center, www.uidcenter.org

Figure 6: RFID tag with barcode from Checkpoint. Source: Auto-ID Center Technology Guide.

Table 3: ID Tag Classifications

Class	Type	Description
Class 0	Optical ID tag	Can be read by optical means; examples include bar codes and 2D barcodes
Class 1	Low-level RFID tag	Read-only RFID devices for contactless communication that reveals the entire content when read
Class 2	High-level RFID tag	Read-write RFID devices for contactless communication that reveals the entire content when read
Class 3	Low-level smart tag	Tags with computing power (such as process and encryption coprocessors) for contactless communication. The encryption and authentication of the tags is supported by secret-key encryption
Class 4	High-level smart tag	Smart tags with compute power for contactless communication. Encryption and authentication is supported by public-key encryption
Class 5	Low-level active tag	RFID tags and sensor nodes with batteries or miniscule power generators. These function independently without an external power supply, but are not equipped with processors and have no computing power.
Class 6	High-level active tag	Tags are tiny computer nodes with batteries or miniscule power generators. These function independently without an external power supply and are equipped with processors for computing functions
Class 7	Security box	Safe and secure high-capacity computer nodes with tamper resistant enclosure and support for wired network communication. These are assigned an eTRON ID and supporting Entity Transfer Protocol (eTP)
Class 8	Security server	Class 7 characteristics, but operated under stricter security procedures.

10.1.5.3.2   RFID Frequencies & Emerging Standards

Though the 13.56MHz band is considered 'global,' RFID tags operate at various frequencies, ranging from low frequency to microwave frequency. Table 4 shows operating frequencies for passive RFID tags.

Due to varying government regulations, there are regional operating frequency differences for RFID systems. Geographic areas, such as Europe, North America,

and Asia, have specified different operating frequencies for the EPC tags to operate. For example, tags designed for the North American market typically operates at 915 MHz. European tags operate at different frequencies, including 13.56 MHz, 800 and 1000 MHz (UHF) and 2.4 GHz frequency bands.[35]

Table 4: RFID Operating Frequencies for Passive Tags[36]

	Frequency range	Read range	Data rate	Typical uses
Low Frequency (LF)	125 KHz	Less than 0.5 meters	Slower	Access control; animal tracking; vehicle immobilizers; POS applications (SpeedPass)
High Frequency (HF)	13.56 MHz	1.0 meter		Access control; Smart Cards; Smart Shelves; item level tracking (airline baggage, library books)
Ultra High Frequency (UHF)	860 – 930 MHz	3.0 meter		Pallet level tracking; tote tracking; electronic toll collection (EZPass)
Microwave Frequency (uW)	2.45 GHz/5.8GHz	1.0 meter	Faster	Supply chain management; electronic toll collection

Tags operating at lower frequencies around 125 KHz generally have shorter read ranges, good propagation, a higher cost, and slower data transfer. These tags are used for animal and livestock tags.

The most popular tags are UHF 860-960MHz.   869.5 MHz is the common frequency (Europe current) and can be read worldwide, but with different performance characteristics.

Higher frequency tags in the 13.56MHz are popular in Europe.   These have relatively short read ranges; lower cost and faster data transfer.   They use inductive technology and so have trouble generating the power to get to the higher read ranges. Typical ranges are 1 meter or less, but most effectively at about 12 inches.

Because of the range of frequencies over which RFID tags might operate at particular locations, readers will have to be very robust. They will have to be able to read in frequency ranges from 856 to 956 MHz for most worldwide applications. Such reader flexibility will be important to the USMC if it is planning on

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[35] Quoted directly from Sun Microsystems White paper: Sun and Auto-ID.   Sun Microsystems White Paper: Sun and Auto-ID. September 9, 2003. p9.
[36] Bear Stearns, "Supply-Chain Technology," June 2003, p. 37

establishing distribution centers in-country that may have different frequency requirements, depending on region.

EPCglobal is currently reviewing a Class 1, generation 2-air interface protocol. Class 1, Gen 2, will be a foundation protocol for all passive UHF tags and will support tags from Class 0 to Class 2. One such protocol has been developed by an international group of RFID manufacturers and technology innovators known as the "Performance Team," to provide the best possible performance in narrow band regulatory jurisdictions such as Europe and the Far east, while maintaining optimum performance where more spectrum is available in the countries such as the U.S., Canada and Australia.[37] The core protocol is optimized for Class 1, Gen 2, but it provides necessary elements to support future Class 2 and 3 tagging systems.   The Performance Team includes Atmel, BTG, EM Microelectronics-Marin, Matrics and RFID Solutions, Ltd.   This protocol submission merges original submissions from Performance and Flexworks team members.

EPCglobal Generation 2 working group is reviewing the Performance Team protocol and Gen2 protocols developed by Alien Technology and its partners, and the Unified Group (a group of 13 vendors, including Texas Instruments, Philips Semiconductors and Intermec Technologies). EPCglobal hopes to reach a consensus about which of the Gen2 protocols are optimal by May 28, 2004. If agreement cannot be reached, the three protocols will be put into independent tests.   The EPCglobal board hopes to ratify a draft standard by October 6, 2004.[38]

10.1.5.4. Tag Readers

RFID readers use a variety of methods to communicate with tags. The most common way to read passive tags at close range is called inductive coupling (the same technology used for key card entry at many companies). The coiled antenna of the reader creates a magnetic field with the coiled antenna of the tag. The tag draws enough energy from this field to send back its EPC. Reader costs are also expected to go down from their current $2,000-$3,000 range to about $1,000 in the next few years, but the cost is expected to become more variable between the lower end and higher end readers. Readers are available which operate with tags designed for different regions.

Experts believe that reader interoperability across geographic regions will be demanded by many users and anticipate that such reader flexibility will emerge. It is not currently available. Readers also are not protocol agnostic. This means that readers designed for one type of protocol will not necessarily read tags

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[37] "Industry Leaders Propose EPC UHF Gen 2 RFID Standard," CNNMoney (www.money.cnn.com), May 13, 2004.
[38] "Two EPC Generation 2 proposals merge," *Frontline Solutions* (www.frontlinetoday.com), May 14, 2004.

produced with another protocol. Thus each reader/tag system must be carefully matched. These same experts caution, however that readers will vary in their ability to handle differences in tags and frequencies and expect to see greater cost differentials between readers in the future.

EPCglobal will have a testing facility to uncover interoperability issues between tags and readers. They anticipate developing an RFID interoperability certification to help potential users sort through whom technologies will work with which tags based on the tag's underlying protocols (See the standards discussion earlier in this report).

Another important consideration of readers is that they be backward compatible with existing tags.

10.1.5.5. The Savant

In an environment where readers are picking up a nearly constant stream of EPCs, managing the data is a significant task. The Auto-ID Center has designed software technology called The Savant to act as the leading edge of this infrastructure. The Savant distributed architecture gathers, stores, and processes EPC data from one or more readers. Savant's also smooth data, correct duplicate reader entries, intelligently store and forward data up or down the chain, and monitor for events (low stock level, for example). Then, Savant servers pass data up to the ERP systems, through a full time connection, or synchronizing data on an "as needed" basis. The Savant framework consists of a set of geographically distributed servers. Savants are connected to RFID readers which continuously collect EPC data from tags, and feed this data to the Savant.[39]

Recently Microsoft has formed an RFID council to help it develop ways to comply with RFID mandates, to help companies achieve operational efficiencies and to help these companies link to ERP systems. The support for evolving middleware could be enhanced by this collaboration, which includes Microsoft, Intermec, Accenture, GlobeRanger, highJump Software, Manhattan Associates, Metro (a German retailer rolling out RFID), and Provia Software.[40]

10.1.5.6. RFID System Vendors and Early Adopters

Though multiple industry uses can be identified, there are key players across the supply chain to watch from a commercial adoption standpoint. A July 2003 report summarizes some of the key tag and reader vendors, software players and early adopters. See Table 5.

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[39] This section is quoted directly from Sun Microsystems White paper: Sun and Auto-ID.   Sun Microsystems White Paper: Sun and Auto-ID. September 9, 2003. p7.

[40] Krill, Paul (writing for InfoWorld), "Microsoft forms an RFID council, April 6, 2004, on the web at www.computerweekly.com

Table 5: A Sample of RFID Players[41]

Tag Vendors	Reader Vendors	Software Players	Early Adopters
Alien Technology Corporation	Intermec Technologies Corp.	Descartes Systems	Boeing
Intermec Technologies Corp.	Matrics Inc.	EXE Technologies	CHEP
Matrics Inc.	Psion Teklogix Inc	GlobeRanger	Georgia Pacific
Phillips Semiconductors	SAMSys Technologies Inc	Manhattan Associates	Gillette
Savi Technologies	Symbol Technologies	OATSystems	International Paper
Texas Instruments	Tagsys	RedPrarie	Marks & Spencer
	Tyco Sensormatic	SAP	Wal-Mart

It should be noted that Table 5 (and Table 6 following) are drawn from a comprehensive and non-biased summary of emerging RFID technologies and vendors. This report, which was produced in June 2003, unfortunately, is nearly a year old. With the pace of change in this infant industry, this information (and, in fact, the information presented in the current document) may not remain current into the future.

Experts suggest that one RFID system does not fit all applications. They urge that the technologies be matched to the particular application, and suggest that a case-by-case analysis be done to determine the unique features of the system needed and to identify the best in class in the industry at the time of application. Experts also suggest a "Tag Evaluation Plan" to determine what factors will be important in the initial implementation and to help define heuristics that will facilitate rolling-out the application to another location. [42]

Within the RFID system, there has been more focus on the RFID tags than on other parts of the system, such as reader vendors or software players. RFID reader costs are actually a significant part of the system's costs. Several vendors make both readers and tags. Experts believe that most of these vendors are producing both tags and readers to demonstrate their systems, but that in the future vendors will focus on one or the other.   For the systems to attain their potential, supply chain execution software companies must play a key role in the system. See Table 6 for a summary of vendors and their product attributes.

In point of fact, this segmentation of the industry is, indeed, happening. Vendors appear to be specializing in one or two areas of the system, relying on other vendors to supply additional components. Emerging solution providers are helping to configure systems that will work together and that match the application.

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[41] Bear Stearns, "Supply-Chain Technology," June 2003.
[42] Alien Technologies offers a 2-day "RFID Bootcamp" for potential users and their technical support staff.

Table 6: Characteristics of RFID Players[43]

Tag Vendors	Label Vendors Targeting RFID	Reader Vendors	Software Players
Matrics Tags have superior read ranges, accuracy and reliability Tags are orientation insensitive. Compliant with Auto-ID Center's EPC. Ultrahigh frequency (UHF) tags have broad adoption on pallet and case level Is considering licensing its technology for tags **Alien Technology** 500-million tag order from Gillette** involved in Auto-ID field trials Patented manufacturing process called fluidic self-assembly (FSA) will reduce per tag cost **Texas Instruments** Company is large player in RFID space Largest number of tags in real-world situations (as of June 2003) Focus on high frequency tags will best serve item-level tracking ** Gillette later scaled this order back and is now piloting tracking at the case/pallet level	**Zebra Technologies** Sponsor of Auto-ID Center Partnering with Manhattan Associates **Avery Dennison** Sponsor of Auto-ID Center Strategic partner of Alien Technologies **Flint Ink** Privately held manufacturer of inks and coatings Developed a way to print inexpensive antennas using conductive inks Collaborated with Scotland-based RT Circuits (which has proprietary technology for printing conductive materials) Collaborated with Alien Technologies **KSW-Microtec** Has developed RIFD smart labels with integrated temperature sensors Has developed RFID labels that are washable and can be sewn or ironed directly into fabric German-based company	**Intermec Technologies** Offers wired and wireless automated data collection, RFID and mobile computing systems Broad array of patents RFID offering separate from its bar code reader technologies Focusing on low-cost RFID pilots Readers can read multiple forms and protocols **Symbol Technologies** Background in bar code data capture Actively partnered with several RFID tag manufacturers Developing readers that will do both RFID and bar codes Leading provider of auto-ID solutions using bar-codes in retail **Matrics** Maker of both RFID tags and readers May have early advantage in reader sales since appear to have superior read ranges on their RFID tags Is considering licensing its technology for readers	**Manhattan Associates** Judged to have superior position in RFID supply chain applications Over 900 customers in supply chain execution, with aggressive pursuit of RFID space Has developed "RFID-in-a-box" solution with Alien Technologies **SAP** Worked with Metro AG in a pilot program to track assets using RFID at the pallet level

One supply chain execution software vendor, Manhattan Associates, is working across the system suppliers to provide customers with an "RFID-in-a-box" concept. The solution includes all elements needed to begin initial deployment and utilization of RFID technology, including RFID readers with two antennae per reader as well as a fixed number of RFID tags from Alien Technology Corp. to label and track goods.

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[43] Adapted from Bear Stearns, "Supply-Chain Technology," June 2003; note on Alien Technology added.

Customers will receive a limited license version of Manhattan Associates' Trading Partner Management (TPM) application, allowing them to enable their suppliers to remotely generate RFID tags and apply them to goods. It also will include remote Electronic Product Code (EPC) printers to print the RFID tags. [44] Manhattan Associates considers itself a warehouse management company, rather than an RFID company per se. With this focus, the company emphasizes efficiencies across both the technologies and the underlying processes that the technologies are intended to support.

Dan Bodner, director of data capture at Intermec Technologies, notes that reader placement is important to eliminate interference with wireless LAN systems, among other things. He suggests that starter kits are a good way to test various transponders and tags. Depending on their configuration, starter kits range from about $3,000 to $14,000.

In addition to the vendors listed in Table 5, there are several systems integrators currently targeting the RFID supply chain application market, including Accenture, IBM Global Services, U.K-based Intellident and privately held Xterprise.

Another emerging player, Sun Microsystems, in September 2003 announced an initiative for delivering the hardware, software and services that enable enterprises to link into the Electronic Product Code (EPN) Network. Sun's approach will enable enterprises to integrate real-time supply chain data seamlessly into their existing business processes and enterprise assets. The technology behind Sun's Auto-ID effort will be similar to the technology behind RFID tags.

Specifically, Sun claims its software will deliver a dynamic federated service architecture that emphasizes reliability, availability and scalability (RAS) for Auto-ID pilots and deployments. The proposed solutions also will include lifecycle services to maximize the value of Auto-ID deployments, helping customers proactively architect, implement, and manage IT operations in heterogeneous environments. Most of the company's EPC offerings will be delivered through the Solaris OE and Linux-based hardware platforms, setting the stage for transparent integration into the EPC Network. [45]   The system architecture was displayed earlier in Figure 4.

Another integrator, webMethods, has developed a flexible web architecture that supports the integration of multiple databases, systems and communication methods into a seamless framework.

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[44] Manhattan Associates press release, "Manhattan Associates and Alien Technology Corp. Announce 'RFID in a Box' Supply Chain Solution," June 11, 2003
http://www.manh.com/news/news_releases_20030611_rfid_box.html
[45] Villano, Matt, "Sun Expands Push For Auto-ID." *InternetNews.com* , September 19, 2003.

10.1.6. Commercial Use of RFID Tags

RFID systems have been around since World War II when the British mounted transponders to their aircraft to tell via radar whether an incoming plane was one of their own, but until recently most applications were close-loop proprietary systems, often with items tracked within a specific location. Currently, RFID tags require external antennas to read them. The tags themselves cost about 20-75¢ and up per passive tag, and are more expensive for semi-passive and active tags. Analysts believe that a more reasonable cost to achieve widespread commercial adoption is a target price of less than 05¢ per passive tag.[46] Recently Hitachi has reduced the antenna size and has embedded it into chips. Hitachi hopes to sell these for as little as 04¢ per tag by 2006.[47] At this price, some interesting clients emerge, including banks that are considering embedding such a tag into currency to reduce counterfeiting.

Accenture analysts predict that by 2005, many retailers in consumer electronics, grocery, pharmaceutical and apparel industries will be the early adopters of RFID tag technology. Inventory management and out-of-stock applications are the highest priority for auto-ID technology currently. Others believe that the most rapid adoption of RFID technology will come in the automotive and aerospace sectors as these sectors try to deal with federal mandates.[48] Based on attendance at the DOD RFID Summit, this belief appears correct.

10.1.6.1. Tracking at What Level?

Tracking inventory can happen at the individual piece, the box, the pallet or the large-scale container. The level at which to track is important when considering the specific application. During the Gulf War, the Army had nearly 40,000 containers whose contents had to be manually verified, thus reducing total asset visibility and increasing time to process dramatically.[49] As the USMC deploys a large force to a remote location, it might send multiple cargo planes and/or ships laden with supplies of various kinds. Tracking all of these supplies at the individual level may prove cumbersome. A parallel in the commercial shipping industry exists.

In marine applications, for example, inventory is often tracked at the TEU, the Twenty- foot Equivalent Unit, or a 20-foot container. Practically speaking, technology exists today that enables large port facilities to track inventory at the TEU level using Differential Global Positioning System (DGPS) and real-time

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[46] Teresko, John, "Winning with wireless," *Industry Week*, June 2003, p. 60-66. The projection of less than 5¢ for an RFID tag is in question, however. Bear, Sterns, Inc. anticipates a 10¢ per tag as a more realistic cost ("Tracking the Future The Impending RFID Based Revolution; June 2003).

[47] "Radio ID tags so cheap they'll be everywhere," *Business Week*, October 20, 2003, p. 147.

[48] Albright, Brian. "RFID gains momentum," *Frontline Solutions*, September 2003, p. A7.

[49] Hyland, Tricia, "Advancements in wireless capture attention," *Transportation & Distribution*, February 2002, p. 20-25.

locating system (RTLS) technology solutions.[50] The most common approach is to track the location of the equipment that moves the containers.   The equipment is tracked either by installing a DGPS receiver onto the equipment or by using RTLS tags. The challenge with these systems is that the tags must be associated with the actual cargo contents and often this is done manually or with bar codes.   Both approaches involve a network of sensors on the vehicle. Automated container tracking decreases the non-valued added labor costs of searching for containers. It still requires that each container somehow be associated with its contents.

One current military application of pallet-level RFID tracking is the U.S. Transportation Command (USTRANSCOM), headquartered at Scott Air Force Base, Ill. USTRANSCOM acts as the single manager of America's global defense transportation system.   During Desert Shield and Desert Storm operations, the command center moved approximately 504,000 passengers, 3.7 million tons of dry cargo and 6.1 million tons of petroleum.[51]   Today, USTRANSCOM is using RFID tags at the pallet level to monitor air cargo bound for five U.S. aerial ports and two overseas (Ramstein Air Base and Yokota Air Base). The cargo being tracked includes rations and repair parts.

USTRANSCOM transfers information about the contents of the pallet to an RFID tag that is then mounted on the plastic mesh netting that secures the pallet contents. When the pallet is unloaded at its destination, a fixed location reader updates the DoD's information systems worldwide to identify the pallet and its current location. For locations that do not have fixed readers, a hand-held scanner is used.

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[50] Werb, Jay and Sereiko, Paul, "How wireless technologies can cure (marine) terminal ills," *Frontline Solutions*, January 2002, p.42.
[51] Katz, Jonathan. "Armed to the teeth with RFID tags," *Transportation & Distribution*, July 2003, 44(7): 18.

Table 7: Savi Technologies and its Competitors[52]

Top Competitors	Other Competitors
- Intermec Technologies - Phillips Semiconductors - Texas Instruments	- Activant Solutions - Atmel - AXCESS - Brady - Gemplus - LXE - Microchip Technology

The tags are supplied by Savi Technology, which has been awarded a $90 million three-year contract with DoD to provide RFID tags and related logistics software. Savi is one of several vendors working in this area. See Table 7.

Forrester Research estimates that the most common use of RFID technology currently is at the container level. Workers scan pallets at the distribution and warehouse stage rather than tagging individual items.[53] Retailers will change this dynamic as they adopt RFID to track high margin merchandise.

Several executives have noted the public's concern about privacy issues in tracking individual items. Though some stores have used it in pilot tests for individual items that are purchased by customers, privacy issues are a concern, particularly in Europe.

One aspect of item-level tracking that may have interest for the military is in tracking clothing and associating it with a particular individual. This might facilitate laundry handling (a lesser activity), but might also facilitate identification via clothing. The trade-off here is in putting a tag into clothing that cannot be read from a great distance so as not to put the warfighter at risk for targeting through tag identification or location. Texas Instruments technology has developed a tag that is used in current laundry applications that can be read from 6 inches, but not from much beyond that. This tag may offer opportunities to tag clothing items without creating a targeting issue for the wearer.

Though an extreme application, one DoD supplier suggested that an unanticipated use of RFID might be to arm land mines with readers. These mines, generally sensitive to pressure to detonate, might someday be sensitive to a human RFID tag wearer or someone who is carrying an RFID-tagged item within the vicinity to detonate. Though not available currently, this is a decided harmful, but not inconceivable, use of RFID technology in warfare.

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[52] Hoover's Online, The Business Information Authority; October 24, 2003 internet search.
http://premium.hoovers.com
[53] Bednarz, Ann, "Wireless technology reshapes retailers," *Network World,* August 12, 2002, p. 23.

10.1.6.2. Comparing RFID and GPS for Locational Tracking

There is a distinct difference between applications using RFID and those using GPS to track inventory. Global Positioning Systems are generally used to track parts moving on a global scale. RFID, on the other hand, is used to track parts when a shipment and/or part pass a specific point on its journey. Generally RFID is most useful tracking items within the store, yard or warehouse.[54]

One unique application of wireless tracking of "inventory" using GPS is by a commercial wine grower. Scan Control, based in California, has developed a GPS-based system that enables growers to track grape growth using mobile devices. This system allows workers to walk down a row of vines, input information, and through GPS have that information associated with specific latitude and longitude coordinates to link the information to a specific set of vines. This technology replaces the bar codes, which had been placed on posts at the start of each row. [55]

10.1.6.3. The Wal-Mart Initiative

One early adopter that is sure to drive RFID use is Wal-Mart. In June 2003, Wal-Mart Stores, Inc. urged its top 100 suppliers to deliver pallets and cases equipped with RFID by 2005.

Wal-Mart began its focus on item-level tracking but soon realized that such tracking was not feasible technically or cost effective economically for most items. Current Wal-Mart thinking is that cases will be RFID-tagged and that these cases will be associated with a pallet. Coming in to the warehouse or store, the pallet will be read with 100% accuracy. Then, since each case is associated with a pallet, the cases can be transferred from the pallet and read as the case runs along a conveyor belt with 100% accuracy.

Wal-Mart is pressing its top 100 suppliers to become RFID compliant, but noted that in this pilot phase; an additional 37 suppliers have asked to participate. The company is focusing on the store level primarily. Wal-Mart's planned roll-out of RFID tracking is as follows:

- 2004   case/pallet level tracking with key suppliers in pilot project
- 1/2005   top 100 (plus volunteers) go live with case/pallet tracking
- 2005/2006   All suppliers go live with case/pallet tracking
- 2005 and beyond   specialized item level tracking
- 2005 and beyond   5¢ or less for item level tracking.

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[54] Roberts, Simon, "Tracking parts in transit," *Frontline Solutions Europe*, May 6, 2003.
[55] Tierney, Stephen, "Mobile technology in the field," *Frontline Solutions Europe,* April 1, 2003.

Wal-Mart executives believe that it will be 10-15 years before every item is tagged and tracked within its stores. [56]

According to a study published by Forrester in March 2004, a majority of Wal-Mart's suppliers will not be able to meet the retailer's January 2005 deadline for adopting RFID. In the report, Forrester said it had reduced its estimate of the number of companies it expects to meet Wal-Mart's mandate from an earlier estimate of 60 percent to only 25 percent. Forrester said it based this estimate in part on interviews it conducted with the companies.[57]

Moreover, experts predict that a $12Billion supplier of Wal-Mart will spend more than $9Million on tags, readers, servers, application software, middleware and internal and external services with the three pilot distribution centers that Wal-Mart has identified for Phase 1 testing. Even the hardware implementation needs are unclear at this point since as many as three readers per dock door may be needed to meet the retailer's requirements.[58]

One of the first eight companies to ship pallets and cases to Wal-Mart marked with RFID tags is Unilever North America. Unilever partnered with RedPrairie Corporation to develop its RFID pilot. Three Unilever locations are active in this pilot, which provides 'agents' to collect and verify RFID tag information, retrieve related inventory data and pass this combined information to the retailers (Wal-Mart being one of the first) in advanced shipping notices (ASNs). The process provides case and pallet level RFID information through the ASNs.[59]

In January 2003, Gillette ordered 500 million RFID tags from Alien Technology in Morgan Hill, CA.[60] Gillette justified its investment as a way to fight the "empty shelf" problem. Typically, consumers seeking to purchase consumer goods expect to have shelves fully stocked. Gillette conducted field trials at Wal-Mart in Brockton, MA and Tesco's Cambridge, U.K. store. The company hopes to create an intelligent shelf that tracks customer purchases and alerts the company's order fulfillment system when supplies are running low. The intelligent shelf also is intended to help the company identify when abnormally large amounts of stock are being removed, such as might be the case with theft.

Gillette found that it is easier to conduct tracking at the case and pallet level and has since scaled back its item level tracking in a smart shelf approach. The company hopes to attain this item level eventually, but for now they are now focusing on tracking Venus women's razors on their supply line at Devens, MA,

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[56] Remarks, Mr. Simon Langford, RFID Strategy, Wal-Mart at the DOD RFID Summit, April 2004

[57] Hines, Matt, "Companies' RFID plans fuzzy so far," *CNET News.com*; reprinted from ADNN located at http://www.zdnn.com, April 15, 2004.

[58] Bordinaro, Michael. "RFID Keys to Success," *Frontline Solutions,* (www.frontlinetoday.com) April 1, 2004.

[59] "Unilever partners with RedPrairie on RFID pilot," *Frontline Solutions* (www.frontlinetoday.com), May 6, 2004.

[60] Teresko, John, "Winning with wireless," *Industry Week*, June 2003, p. 60-66.

for the packaging and distribution center. At the case and pallet level of tracking, Gillette is attaining 100% read accuracy. [61]

10.1.6.4. Reusable Container Tracking

Another use of RFID tagging has been for high-value items or for tracking reusable containers. In addition, RFID tags are being implemented in some harsh environment applications commercially, particularly where the container is reused. For example, in Britain, the Carlsberg-Tetley Brewing Company is equipping its beer kegs with RFID tags to track them throughout their life cycle (production, delivery, use, recovery, and reuse). The life of these kegs is a minimum of 15 years and the tags must withstand the rigors of transportation, washing and rowdy pubs.   Reusable container tracking is moving ahead faster in Europe than elsewhere due to the stiff landfill taxes that discourage companies from scrapping containers.[62]

Marks & Spencer has replaced bar codes with RFID tags on about 3.5 million of its reusable trays that it has in its refrigerated foods supply chain. The RFID tags reduce the time it takes to read multiple trays and containers stacked on a pallet by about 80%. A complete dolly or pallet with 25 trays can be scanned in a single pass through an RFID portal in five seconds with high accuracy compared to the 29 seconds it previously required using bar codes. Truck unloading has similarly been reduced with the move to RFID from 18 minutes with bar codes to three minutes with RFID tags.[63]

A USMC parallel to the Marks and Spencer tracking would be tagging of particular containers that are used for unique equipment or supplies. This would help locate and identify appropriate reusable shipping packaging/containers and could potentially improve supply packing efficiencies in terms of time, while also decreasing in-shipping damage to critical equipment by matching it to the "correctly" designed package/container.

Radio waves are absorbed by water and are distorted by metal. CHEP, an international pallet and container company, is using RFID technology to track its assets through repair and inspection facilities. Most of CHEP's pallets are made of wood, a retainer of water. In addition, CHEP experienced problems with metal interference in its warehouses. The company was able to "design around these obstacles" by using a forklift mounted solution to minimize the metal interference.[64]

[61] Bordenaro, Michael. "RFID: Keys to success," *Frontline Solutions* (www.frontlinetoday.com), April 1, 2004.

[62] Albright, Brian, "Extreme environments," *Frontline Solutions,* February 2003, p. 16-21.

[63] Bear Stearns, "Supply-Chain Technology," June 2003, p. 29

[64] Hyland, Tricia, "Advancements in wireless capture attention," *Transportation & Distribution*, February 2002, p. 20-25.

CHEP is working with GlobeRanger, RedPrairie, Franwell and Verisign to track inventory across multiple supply chains. CHEP ships RFID tagged pallets to the manufacturer. CHEP's inventory system is automatically updated with the pallet information and the EPC information services system is updated for pallet tracking purposes. The manufacturer then loads the pallet and associates the cases to the pallet. As the pallet is filled, RFID readers scan the pallet as it leaves the manufacturer's facility and an advanced shipping notice is sent to the distributor.

This application, even with its limitations of tag and pallet material compatibility, is one that has strong parallels to the USMC. The software and hardware combination may offer insights into ordering, packaging, palletizing and subsequent shipping and receiving to USMC remote locations.

Another pilot of RFID tracking for reusable containers points to the importance of having the entire supply chain ready to implement RFID to reap benefits. Georgia Pacific introduced reusable plastic containers for its shippers to use in transporting perishable goods from grower through the distribution chain to the retailer. The plastic trays were collapsible after use and so Georgia Pacific was interested in tracking the trays not only during use, but also during recovery (similar to CHEP) to make sure that customers were returning the containers. Georgia Pacific was able to successfully track the location of the containers, and to reinventory them after return at a rate 25 times faster than manually. However, the company abandoned its pilot program since it didn't see efficiencies and benefit across the breadth of the supply chain to justify the costs. Georgia Pacific will likely reconsider this approach for more expensive perishable items such as meat.

Raxel, a South African company, is using RFID tags to track reusable containers that are used to handle hazardous waste. The read/write passive tags enable any employee to immediately identify the contents of the container, its status in the hazardous waste disposal stream, and ultimately, the container's cleanliness after emptying, to prepare for reuse.

10.1.6.4.1. Distribution Centers
10.1.6.4.1.1. Commercial Distribution Centers

Nowhere is supply chain visibility more important than in environments where goods are coming from multiple sources and then going to multiple locations. In fact, visibility is the foundation for supply chain efficiency, particularly as it relates to description and location and the make-up of incoming and out going shipments.[65]

Inventory tracking is particularly challenging in commercial distribution centers. These companies bring together merchandise from a variety of suppliers and

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[65] Krizner, Ken, "All eyes on the Supply chain," *Frontline Solutions,* April 2002, p. 12.

then redistribute it to several customers. Thus their order fulfillment and tracking is complex. Third party logistics providers indicate that the use of RFID technology will greatly reduce check-in/check-out time, unloading time, and time needed to record inventory. Commensurate reductions in labor needed, and associated reductions in errors, are also anticipated.[66]

Jiffy Products of America,[67] located in Batavia, IL, supplies goods to Home Depot, Wal-Mart, Walgreen Drug Stores and Lowes, among others. Jiffy implemented Exact Macola Software's live inventory and order entry modules[68] to help control its inventory. At its peak, Jiffy estimates that it turns over 40% of its warehouse inventory on a daily basis.

ES3 LLC in York, PA is another company using wireless technology combined with bar codes to track trailer-level shipments. The company is using WhereNet wireless location technology to provide instant visibility to all of its 1,900 trailer slots. ES3 is a supply chain services company that co-locates the inventories of multiple manufacturers.

ES3 is tracking trailer movements within its distribution center using WhereNet's YMS software, with 802.11b technology. Trailer movement is tracked through rugged mobile devices that are mounted inside each of the switch tractors. Whenever a trailer is moved, WhereNet software displays the location of the trailer and links it to a map of the distribution facility. WhereNet provides yard management software combined with a wireless location application.

WhereNet is also being used to track and update container positions within marine applications.   The solution supports identification of the grounded container number. Containers are updated each time they are moved by a crane within the shipyard. WhereNet tags have a 1.5-meter accuracy and currently cost approximately $55 each with a lifespan of 5-7 years.

WhereNet is different from Savi Technology, which also uses tag to track location. The WhereNet tags are associated with a master database. Savi, on the other hand, maintains data with a tag association directly. WhereNet is being looked at by car rental agencies and can be combined with other sensors to capture multiple data.

10.1.6.4.2. Staging Area at Norfolk Ocean Terminal

David Cass, Transportation Systems Analyst, Fleet and Industrial Supply Center Norfolk, Ocean Terminal Division, shared his experiences with RFID implementation at his location.[69]   The Norfolk Center has a large variation in

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[66] Bear Stearns, "Supply-Chain Technology," June 2003, p. 28
[67] www.jiffy.com
[68] www.macola.com
[69] Mr. David Cass, Transportation Systems Analyst, Fleet and Indsutrial Supply Center Norfolk, Ocean Terminal Division, Remarks at DOD RFID Summit, April 2004.

sizes between items and pallets. To accommodate rapid identification and tracking of incoming shipments, the Center is using Alien technology with readers that have a circular antenna added to each receiving station. The receiving software is tied to the reader to marry shipment information to tag information. The Center has maintained backward compatibility for tagged items, having a bar code or 2-d bar code on each tracked item also.

Alien Technology partnered with Science Applications International Corporation (SAIC) to install readers at receiving workstations and to apply RFID tags to all shipments. The shipping dock was equipped with Alien readers and antennas in a mobile tunnel configuration to enable all outbound shipments to be read. In total, RFID equipment used in the six-week trial included 13 readers and 16 antennas. To date, 15,000 tags have been used (Class 1 EPC tags).[70]

The Norfolk application has a human in the system to accommodate the variations in size of items on a pallet. Current technology cannot read 100 envelopes in a small area, for example, with 100% accuracy. This is compounded by the many boxes of various sizes (and often containing RF unfriendly contents such as metal and liquids).

As the pallet is loaded onto the forklift, which will bring it through the RFID portal (where the readers are located), the driver must know how many box counts are on the pallet. Norfolk uses an odometer type of reader. If the manual count reader and the RFID reader don't match, then the cases must be taken through the portal manually. Because of this Cass cautions that an unmanned portal is probably not going to happen in the near future and implementation projects should be budgeted accordingly.

Norfolk has determined that label placement is very important to their system performance. Unfortunately, incoming cargo is not standardized. The traditional way to label freight is line of sight. This tagging won't necessarily work well for RFID tagging. For humans, the best placement is on the front of the box; for RFID system reading, the best place for the EPC readable tag is on the side. Norfolk has been experimenting with putting the EPC tag as close to the edge as possible on the front of the item or case.

The Norfolk Center has also begun to identify serious problems with 55-gallon drums, which they have been able to tag by using foam backing to separate the tag from the drum. Another problem arises in trying to read RFID tagged boxes containing metal containers.

Staging near the portal has proven to be a problem since elements staged near the readers were tending to interfere with read accuracy. This has resulted in a

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[70] For more information, contact Kyra Whitten at Alien Technology, kwitten@alientechnology.com; Source: Department of Defense completes successful RFID trail using Alien Technology tags and readers," www.businesswire.com; April 13, 2004

reading portal that is much larger than they initially planned and so Mr. Cass was not able to put a reader at every entrance as was originally planned. The existing portals are in an arch of about 12 foot square, with about 6-8 feet separation between the first and second sets of readers. An additional 8-10 feet of dead space on all sides is needed. Norfolk is building a tunnel to enclose the portal and hopes that this will reduce the footprint.

Norfolk also discovered that standard square pallets were not giving 100% accuracy in case reading. Through experimentation, they have developed a donut shaped pallet on which items can be placed with RFID tags facing outward. Though they recognize that this is a long term business issues due to the tradeoff between reading efficiency (circular pallet) and shipping efficiency (square pallet), Cass expects that the wasted space inside of the circular pallet will decline over time as the reading technology gets better.

10.1.6.4.3. Wireless Technology to Facilitate Re-labeling with Bar Codes

Current USMC shipping practices include bulk pallets that are then reconfigured into smaller batches for distribution. To successfully track individual items or smaller packages, new bar codes must be prepared as the larger pallets are resized. Bar codes are printed in much the same way as other labels. Printers are fed data from a database associated with the bar code or EPC (or UID) code and can then reformulate a new bar code or tag for the remaining pallet items. Printronix has developed a printer that combines both bar codes and RFID tags into a single label that can be attached. This option could replace the need for re-writeable tags on pallets that will be reconfigured along the logistics chain.

Relabeling requires that printers be located within close proximity to repackaging areas. Intermec[71] has developed a wireless solution to facilitate wireless printing of bar codes. In this way, repackaging areas can be located anywhere and printers can support them without network cabling. This reduces the complexity of repackaging and staging areas. The EasyLAN Wireless product uses Dynamic Host Configuration Protocol (DHCP) that allows the host system to assign a reusable IP address to the printer. This product is uses an industry-standard 802.11b radio and has 64 or 128-bit WEP encryption for network security.

It should be noted that the 802.11b encryption framework is not as robust as the USMC might require. Encryption continues to be of major concern to commercial applications running wireless. An emerging protocol 802.11i for wireless encryption is slated to become an IEEE standard in summer 2004. However, since Microsoft and Cisco are adapting different WLAN authentication technologies, interoperability issues will surround encryption systems.[72] New

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[71] Intermec has over 25 years of experience with wireless systems and includes among its customers NASA, Hertz and BMW. On the web at www.intermec.com or 1-800-347-2636.
[72] Messmer, Ellen, "Wireless LAN worries," *TechNewsWorld*, January 19, 2004. www.technewsworld.com

systems operating with 802.11i will require a new generation of WLAN equipment, an additional and perhaps unanticipated expense in wireless applications. The Wi-Fi Alliance and TrueSecure's ICSA Laboratory are among the organizations planning to conduct interoperability tests.

10.1.6.6. Item Tracking within a Fixed Location

Owens & Minor, a Fortune 500 company and leading distributor of medical and surgical supplies to hospitals and healthcare systems is using RFID to track the location of its products within locations (for medical worker visibility) and within its distribution centers (to provide asset visibility and track inventory levels). Patrick Caine, a business systems developer for Owens & Minor notes that being able to tie inventory tracking effectively with an ERP system is a major challenge, saying, "Middleware is a tremendous void in the industry."[73]

The Gap, for example, has realized inventory accuracy levels of 99.9% in their in-store trials of RFID at the piece level.

At a larger level, O'Reilly Autoparts,[74] located in Springfield, MO, manages about 100,000 stock-keeping units (SKUs) in four distribution centers. This company, named retailer of the year in mid market range by RIS News,[75] supplies parts to auto repair shops and 515 retail outlets. For them, having the right inventory in the right place is essential. The company implemented NonStop's Score forecasting and replenishing software[76] and uses combination software to enable EDI and supplier connectivity over the web.

Staples, another 2003 RIS retailer of the year in the tier 1 category, use handheld wireless devices for its floor associates. The IT solution is a services oriented architecture that includes IBM's Websphere.

10.1.6.7. Item Level Tracking during Manufacturing & Assembly

Ford Motor Company is using WhereNet[77] wireless technology to support its build-to-order manufacturing strategy. Systems typically use a variety of inexpensive radio tags and cellular-reader systems to detect both the presence and location of the tags. Most of WhereNet's customers are large manufacturers that have complex products with expensive components that must be tracked during production. The Ford WhereNet initiative is producing savings at 30 Ford plants in North America and Europe by controlling line movement and reducing inventory.[78]

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[73] Hines, Matt, "Companies' RFID plans fuzzy so far," *CNET News.com*; reprinted from ADNN located at http://www.zdnn.com, April 15, 2004.
[74] www.oreillyauto.com
[75] www.risnews.com
[76] www.nonstop.com
[77] www.wherenet.com. Their solutions complement 80211 wireless LAN systems, Bluetooth and GPS.
[78] Teresko, John, "A wireless revolution," *Industry Week*, July 16, 2001, p 21.

Another company using RFID to eliminate human error associated with more traditional production systems is Johnson Control, located in Livermore, CA. This company produces automobile seats for New United Motor Manufacturers Incorporated (NUMMI), a joint production facility of Toyota and General Motors that uses the Japanese system of Just in Time Manufacturing. Johnson Controls first looked at bar code systems as a way to replace its manual approach, but found that the bar codes were susceptible to the dirty and abrasive conditions of the production floor. Johnson is employing both read/write and read-only tags, depending on the seat production requirements (truck versus car). Using read-only tags, Johnson can quickly track the production of its pallets since a write procedure is not needed. Johnson uses the read-only tags to convey information about the car seat's configuration needs, thus helping inform the production line as a car seat proceeds along its length. This replaces the more traditional manufacturing process of batching like-featured seats together into single production runs.   The information in the read-only tag also helps during product testing by "telling" the test machines which protocol to use in establishing performance metrics. The system increases both productivity and accuracy.

International Paper is using a Matrics solution to track large paper rolls in production. The production environment includes high humidity and dust. The paper rolls are between 62 and 72 inches in diameter. The company has found that putting a tag inside of the core of these rolls is the best solution to track asset visibility throughout production. The company found that it was losing between $1Million and $8Million per warehouse in lost paper rolls, or rolls loaded onto the wrong shipments.   At its Texarkana facility, International paper estimates that it is recovering 44% ROI by reducing lost paper rolls.   With this location, each roll can be tracked to within 3 feet of its location at any point in the production process. The reader was mounted on a forklift and the mobile solution included Teflon antennas in the clamps that hold the paper rolls on the forklift. Information is thus passed from the roll RFID to the reader on the forklift and then wirelessly communicated to a central database in the factory.

10.1.6.8. RFID Tags Track More than Inventory

ExxonMobil uses RFID tags to monitor gasoline purchases at pumps through its Speedpass payment system which operates at 134 KHz, considered a low-frequency application. [Note: A high frequency application would be in the 3MHz to 30MHz range, with many high frequency applications operating at 13.56MHz, generally associated with low-power industrial applications.]   The ExxonMobil Speedpass program combines customer payments and inventory tracking into a single system.

Similarly EZPass enables customers to pre-pay tolls and to pass through tollbooth areas without any contact. The RFID system automatically keeps track of tolls and payments.   RFID has also been used to track library books and the

location of people (secure id's and prisoner bands).   These applications warranted the use of more expensive technology than that currently driving the adoption of RFID for retail and other commercial supply chain applications.

10.1.7. Enterprise Resource Systems & Wireless Technology Options

The real value of RFID lies in the strategic use of the information. Because RFID technology enables real-time, accurate data, it should be matched to applications where the underlying data are strategically significant to the operation.   Paul Fox, Gillette's director of global external relations, notes the complexities of linking the RFID information to the enterprise, and highlights the need to consider not only the technology, but also the actual use of the information.   "We are taking our EPD data and interfacing it with Manugistics [logistics software], Provia [distribution software], and SAP [enterprise integration software].... We want to understand who needs to see data, what data they need to see, how the information is valuable, and who it is valuable to."[79]

Within commercial applications, e manufacturing has been a long-term goal. Such systems are characterized by an integrated plant floor that links individual operations within the plant, and mechanisms to link the plant floor with the broader enterprise, typically through enterprise resource planning (ERP) systems. SAP, Oracle, PeopleSoft or J.D. Edwards has developed the most common ERP systems. These systems are only as good as the data within them. Moreover, the data must be able to reach the point in the system where the information can be acted.   Unfortunately this has often required significant company organizational reengineering to match organizational structures and communication patterns with the ERP architecture.

Recently, software products have emerged to help transport data back and forth among plant systems and between the plant system and the enterprise. This Enterprise Application Integration (EAI) software has four general driving concerns:[80]

- Reduce Work in Process (WIP): reduce the amount of inventory sitting around idle during production while it awaits the next processing step
- Reduce Cycle Time: reduce the time it takes to produce a product from the time it is ordered;
- Improve Asset Utilization: increase asset utilization by reducing the downtime on any given machine and by scheduling so that machines are operating at or near capacity; and
- Develop Fact-based Decision-making: using information from the plant floor to trigger raw material ordering, scheduling, and order promising.

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[79] Bordenaro, Michael. "RFID: Keys to success," *Frontline Solutions* (www.frontlinetoday.com), April 1, 2004.
[80] Pantaleano, Mike. "Integrating plant floor systems – The why and the how," *Industrial Equipment News Online*. www.ienonline.com

ERP systems have successfully helped enterprises improve their decision-making and thus, their bottom-line performance. However, these systems thrive on information that is accurate, up-to-date, and comprehensive.

10.1.7.1. Commercial Use of Wireless Enabled ERP Systems

Commercial users of wireless enabled ERP systems include garment manufacturer, VF Corporation that makes Lee and Wrangler jeans and Vanity Fair lingerie. VR Corp. is installing wireless LANs (Local Area Networks) in 200 manufacturing plants to link manufacturing to ERP systems. The company will also reach into its supply chain with retailers like Wal-Mart. VF Corp. is working with Symbol Technologies located in Holtsville, NY to supply the wireless LANs and RFID devices that will eventually link with the company's SAP system. The company is planning multiple input devices including mobile PCs, wearable computers, bar-code scanners and vehicle-mounted computers with bar-code printers. [81]

10.1.7.2. Sun Example of Enterprise Wide Linking[82]

Sun has developed a demonstration project at its iForce Center in Menlo Park, CA, that uses an Auto-ID system. The hardware configuration is detailed in Figure 7.
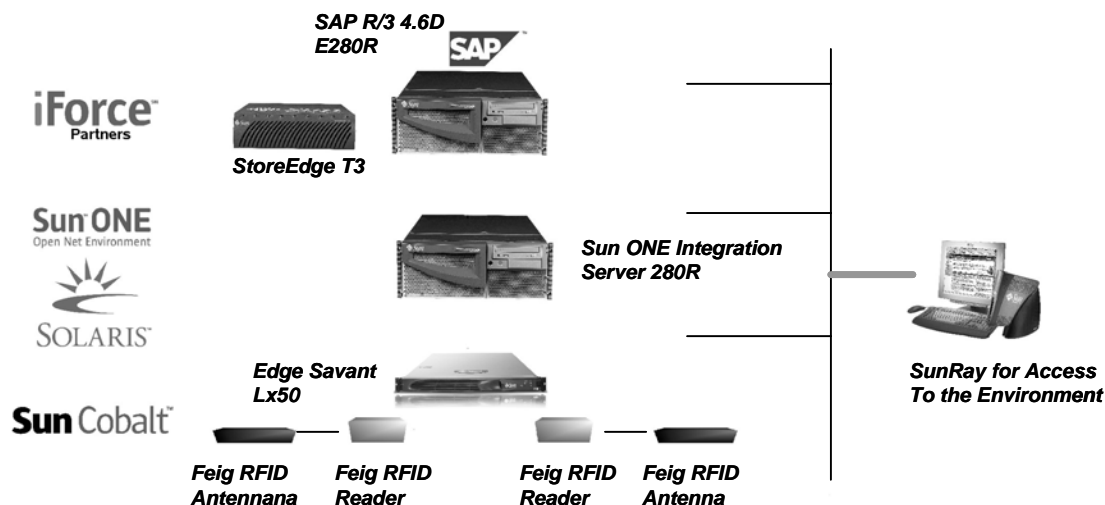

Figure 7: Sun iForce Hardware Configuration Linking RFID System with Enterprise Resource System

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[81] Brewin, Bob, "Garment maker donning wireless," *Computerworld*, September 11, 2000, p. 1.
[82] This section adapted from Sun Microsystems White paper: Sun and Auto-ID.   Sun Microsystems White Paper: Sun and Auto-ID. September 9, 2003. p19.

The company has implemented its Advanced Shipping Notice (ASN) process. Once a shipment has been sent, the customer is automatically notified that it is in process; the customer is alerted to the exact contents of the shipment. This is possible since the pallets don't have to be unpacked to identify their contents – the contents of each pallet are automatically recorded as the pallet passes through the loading dock door. In addition to notifying the customer, the data is also passed to an integration bus where it can be shared with other ERP modules.

The ASN application is built on the Sun™ Open Net Environment (Sun™ ONE). While the foundation software is built with Sun ONE software, (integrated), software from other vendors can be used. In addition, software from iForce partners is also used.

10.1.8. Return on Investment Issues for Wireless

Not all wireless technologies are viewed equally. In fact, 51% of executives in Europe, North America and Australia indicated that they do not fully comprehend the value of wireless applications in their supply chains, many believing that the technology is not mature enough for full-scale deployment.[83] Security, network speed and geographic coverage top the list of barriers to widespread adoption of wireless applications. About 62% of U.S. corporations are planning to pilot or deploy a wireless wide-area data solution within the next two years. In-Stat/MDR estimates that wireless data users will grow from about 6.6 million at the end of 2001 to more than 39 million by 2006.

Table 8 highlights some return on investment information available in the published literature.

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[83] Anonymous, "Wireless marches into mainstream," *Frontline Solutions*, January 2003, p. 32.

Table 8: Examples of Wireless Implementations and ROI[84-85-86]

Company	Supply Chain Application	Approach	Estimated ROI
Cisco Systems, internet gear manufacturer	Incoming Logistics & supplier performance	Private, internet based hub linking manufacturers, distributors and component suppliers	Increased visibility and increased supplier performance
UPS, shipping	Incoming logistics	Using WAN in its distribution hubs. System includes package sorters with wireless ring scanners	Projected payback period of 16 months, with savings of $13.7M/year over the next five years estimated
Avail, aircraft parts distributor	Inventory management	Bar code labels of individual bins of aircraft parts tracked with wireless scanner; data transferred to ERP system	One year payback period for $100,000 project, Anticipated $1M/year in productivity improvements
Hewlett Packard, printing manufacturing facilities	Production	Wireless handheld computers work as an electronic clipboard to automate data collection and disseminate information to technicians; real time updates to HP data systems	Improved productivity 43 min/day/technician; Increased asset reliability 47%; decreased plant maintenance costs 25%.
Perishable Distributors of Iowa, frozen & refrigerated foods distributor	Production & order fulfillment	Voice-activated system with headsets and computers on employee's hip convey directions on location of inventory and order fulfillment requirements	Decreased order errors 90%; increased productivity 20%; reduced new employee training time 60-70%.
Mains Paper & Food Services, fifth largest food service distributor in the U.S.	Warehouse/inventory management	Voice activated inventory pick and pull system. Upgraded 300,000 square foot distribution center with Manhattan Associates PkMS supply chain execution system with Vocollect Talkman voice recognition system, tied together with 802.11b wireless LAN	Error reduction of 25-33%
Associated Wholesale Grocers (AWG), large grocery wholesaler in U.S.	Warehouse/inventory management	Voice activated picking operations	Productivity improvements of 10-15%, reduced costs of bar code labels of over $250,000 annually. Returns (wrong item) reduced by 50% resulting in $1.3 million savings in the first year.

[84] Tam, Patrick. "Going wireless," *Logisticstoday*, July 2003. 44(7):23

[85] Katz, Jonathan. "Going down to the wire," *Logisticstoday*, July 2003. 44(7):26

[86] Kevan, Tom. "Improving warehouse picking operations," *Frontline Solutions*, May 1, 2004.

10.1.9. Implementation Issues

10.1.9.1. Supplier RFID Implementation Strategies

There are three RFID strategies that commercial companies are taking:[87]

Compliance, commonly referred to in the industry as "slap and ship," is the strategy that companies are using when they simply put an RFID tag onto an item, case or pallet since the customer requires the tag. The compliance strategy can work when the supplier has a single distribution point, but becomes less effective when the supplier has multiple locations.

The conservative or middle-of-the-road approach, describes an enterprise strategy that outfits all the relevant distribution centers in its geography with light-level RFID capabilities that allow for the flexibility to implement and ship from any of the distribution centers into any of the markets.

The fully committed strategy is where the supplier has implemented RFID at all of its distribution centers and links this data to ERP systems. This fully committed strategy has maximum risks for the supplier, but also has maximum potential benefits. Fully committed RFID adopters will have more clout with vendors, thus driving the direction of future innovations.

From a USMC perspective, supplier RFID strategies should help rationalize choices among suppliers in the future. Those suppliers that are adopting a slap and ship approach will lag behind those suppliers who are taking a fully committed strategy for RFID. Fully committed suppliers may be in a better position to assist the USMC with its own implementations of RFID solutions, perhaps even driving some key innovations that will be needed to facilitate unique USMC needs.

10.1.10 RFID Implementation Trials

The Auto-ID Center initiated trials of RFID system configurations in 2001/02. CHEP (wooden pallets), Procter & Gamble (Bounty paper towels), Gillette (Mach 3 Razors, 16 pack), Unilever (liquid All Detergent Soap) and Wal-Mart Stores (Sam's Club in Tulsa, OK) participated. The cost of the Phase 1 trials was reported to total approximately $399,000; of this approximately $116,000 was spent for software development. At the end of the trials, the Auto-ID center reported 97% item identification, but only 78% tag identification accuracy. These results suggest that the system elements can function as designed, but that attaching multiple tags to items improves item read accuracy. Most of the problems encountered were with hardware failures or human error. The phase 1 issues encountered included:

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[87] Bruce, Lindsay, (for ITWorld Canada) on the web at ComputerWeekly. Com, "Yankee Group draws up RFID roadmap," April 13, 2004

- Power outage
- Frequency interference
- Loading dock issues
- DSL line router issues
- Lost reader
- Lost inoperative tag
- Lost hard drive
- Damaged antennas
- Data capture unreliable

- Human error
- Installation problems
- Read reliability
- Poor quality of phone line
- Communication between technologies
- Dial-up failure

Table 9 summarizes 21 additional trials that were conducted prior to June 2003. It demonstrates the breadth of system configurations. These and other implementations are presented in Table 10 in section 10.1.10 as they relate to the USMC recommendations.

Table 9: RFID Implementation and Pilot Projects (Source: Bear, Stearns & Company estimates, June 2003)

User	Tag Vendor	Reader Vendor	Frequency	Active/ Passive	Tag Type	Estimated Units	Estimated Price per Tag	Date of Implementation
Automotive								
Ford	Escort Memory Systems	Escort Memory Systems	334 KHz	Active	Read/Write	10,000-12,000	$150.00	1995
Harley Davidson	Escort Memory Systems (Phillips Chips)	Escort Memory Systems	13.56 MHz	Passive	Read/Write	15,000	$22.00	1998
Southeast Toyota (South Africa)	Escort Memory Systems (Phillips Chips)	Escort Memory Systems			Read/Write			
Toyota	Escort Memory Systems (Phillips Chips)	Escort Memory Systems	13.45 MHz	Passive	Read/Write	20,000	$80.00	2001
Brewing								
Scottish Courage Brewery	Phillips	Saco	125-128 MHz	Passive	Read/Write	200,000	$4.00 installed on keg	August 1998
TrenStar	Trendstar (Phillips Chips)	Trendstar	125-128 MHz	Passive	Read/Write	1,000,000	$1.00	January 2003
Consumer Packaged Goods								
Gillette	Alien Technology	Alien Technology	915 MHz	Passive	Read only	500,000,000	$0.05	
International Paper	Matrics	Matrics	915 MHz	Passive	Read only	10,000,000	$0.30	January2003
Revlon and International Paper	Phillips	SIRIT	13.56 MHz	Passive	Read only	100,000	$0.30- $0.40	Summer 2002 *
Logistics								
Beal Solutions	Alien Technology, Matrics	Alien Technology, Matrics						
Lionize Logistics	Alien Technology	Alien Technology	915 MHz	Passive			$0.45	February 2003
Tibbett & Britten								Summer 2002
Manufacturing								
Boeing	Matrics	Matrics	915 MHz	Passive	Read only	15,000-20,000	$0.78	June 2003
Goldwin Sportswear Europe	Texas Instruments	Texas Instruments		Passive	Read/Write			
Malden Mills	Escort Memory Systems	Escort Memory Systems	125 KHz	Passive	Read only	800	$35.000	Spring 2001
Michelin	Escort Memory Systems (Phillips Chips)	Escort Memory Systems	13.56 MHz	Active	Read/Write	600	$125.00	1999
Nestle Company	Escort Memory Systems (Phillips Chips)	Escort Memory Systems						
Retail								
Benetton	Phillips	Psion	13.56 MHz	Passive		15,000,000	$0.25-$0.50	

Continued: Table 9: RFID Implementation and Pilot Projects (Source: Bear, Stearns & Company estimates, June 2003)

User	Tag Vendor	Reader Vendor	Frequency	Active/ Passive	Tag Type	Estimated Units	Estimated Price per Tag	Date of Implementation
Fig Leaves	Texas Instruments	Texas Instruments						
The Gap	Texas Instruments	Symbol	13.56 MHz	Passive	Read/Write	3,000	$1.00	Summer 2001 *
Marks & Spencer	Texas Instruments	Intellident	13.56 MHz	Passive	Read/Write	3,500,000	$1.00	Spring 2002
Metro AG	Intermec Technologies (Phillips Chips)	Intermec Technologies	869 MHz	Passive	Read/Write	10,000	$1.00	April 2003
ExxonMobil	Texas Instruments	Texas Instruments	134 KHz	Passive	Read only	7,000,000	$2.00	1996
Prada	Texas Instruments	Texas Instruments	13.56 MHz	Passive	Read/Write	5,000	$2.00-$3.00	December 2002
Sainsbury's	Phillips				Read/Write			
Tesco	Phillips		13.56 MHz	Passive				September 2002
Wal-Mart, International Paper, Procter & Gamble	Phillips	SIRIT	13.56 MHz	Passive	Read only	100,000	$0.15-$0.20	Early 2003
Supply Chain Tracking								
CHEP	Intermec Technologies	Intermec Technologies	915 MHz	Passive	Read/Write	500,000	$2.00 or less	Spring 2002
Colchester Library	Phillips	Intellident	13.56 MHz		Read/Write			
Georgia Pacific	Intermec Technologies	Intermec Technologies	915 MHz	Passive	Read only	1,000,000	$1.00 or less	November 2000 *
Northwest Airlines	SCS	SCS						1999
Raxel	Intermec Technologies	Intermec Technologies	915 MHz	Passive	Read/Write	500,000	$1.00	2002

* Indicates projects that ended before June 2003 when the report was completed; all other projects were still ongoing at the time of the Bear, Sterns report.

NOTE: The wide range of per-tag price differences in these examples is reflective of two aspects: (1) price differentials between active and passive, with active being more expensive; and (2) lower prices over time as the technology, manufacturing methods and volumes improve.

10.1.10.1. Lessons Learned

Recent trials of RFID tags using the EPC network suggest that implementation issues are critical to system success. One group suggests that in trials more errors resulted from processes (taking the forklift through the wrong door) rather than technology failures per se.[88] In reality, actual deployment is overtaking the trials. Since Wal-Mart has announced plans for its top 100 suppliers to be RFID compliant by 2005, attention is now focused at distribution centers. In this way, the emphasis is on pallet level tracking, and experts anticipate that item-level tracking will not be broadly adopted until nearly 2007; trials of item-level tracking are expected to continue.

Wal-Mart field trials suggest that tags costing 40¢ each can be justified on pallets for market basket items costing $1.75, with 5¢ tags to track per item. Procter and Gamble feels that-item level tracking will only be economically feasible when tag prices drop to about 1¢. Both companies expect that the near term use of RFID in the commercial retail sector will be bar codes tied to cartons that are in turn tied to pallets, with RFID tying the case to the pallet and the pallet being tracked initially. Though packaging hasn't changed to facilitate RFID labeling and tracking, companies expect that this will be the natural progression.

Companies expect to have difficulty with interoperability until several key issues are solved, mainly around standards. The U.S. and Europe are collaborating on creating a common standard, but China may be a holdout in the standard development, particularly as the EPC codes relate to exported items versus items imported into China. Experts expect that China will eventually go to the global standard, but that it may take time.

Class 1, Generation 2 tags that are EPC compliant are expected to be in commercial production within the coming year, but experts don't believe any volume will be available until late in the 4th quarter. Some believe that it will be in 2006, approximately two years after the specifications/standards emerge this fall, that general availability of interoperable system parts becomes reality. Wal-Mart is hoping that reader vendors are already anticipating the demands of EPC compliance and interoperability so that when the final Ontologies and protocols are determined the readers can read new tags as well as be backward compatible with existing tags.

On a broader basis, RFID implementation will suffer from misconceptions and a lack of available technical workforce to plan and trouble shoot installations. For example, safety continues to be a factor that no one can adequately predict. Some believe that RFID will not be safe for direct, prolonged human contact over time. Though this has not been demonstrated, one of the biggest hurdles that the Norfolk Center had was in convincing its workers that the technology was

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[88] Albright, Brian. "RFID gains momentum," *Frontline Solution,* September 2003, p.A5

safe and would not cause sterility or cancer. This has led experts to expect that some applications might also have a dosage meter attached to the human in the system to track RF exposure, perhaps as much for the human's peace of mind as for any real risk.

The current inbound logistics linear forms are not necessarily best for the more networked RFID systems. Traditional linear systems do not reflect the complexity of the supply chain inbound and outbound environment, nor do they reflect the various staging areas of the USMC deployed force.

10.1.10.2. The Fallacy of 'Plug and Play' RFID Systems

The application for which the RFID system is desired has major implications for the needed configuration of the system, the placing of tags, the location of readers, and the efficiency of the RFID system.   Implementation projects are finding that new circular pallets are needed to increase read efficiency for incoming cases in standard receiving areas, that the placement of tags has a major impact on how quickly an incoming batch can be read and identified, and that multi-sized packages on a single pallet or at a single location are difficult to read with 100% accuracy. Tag signal interference and noise continue to be challenges to reading every item on incoming pallets at standard speeds, and this has prompted a less aggressive roll-out of RFID tag technology from the initially planned item-level tracking to case level or pallet level tracking.

The RFID system architecture includes a power source (either a battery as part of the tag or an external source), a chip (which today is about 20% of the cost), substrate on which the chip rests, and an antenna – all for the tag – plus a reader and middleware software to receive incoming signals, separate them and then id the items that are read. Various aspects of this have been detailed throughout this report. Each tag has a protocol, which is written into the silicon and cannot be changed once created.   This is true for every tag (even for read/write tags). The protocol is established when the tag is produced and determines which readers will work with particular tags.   Experts stress that interoperability between tags and readers is **not** currently seamless. Every combination must be carefully tested to determine if the tag/reader combination will work in the application desired.

Based on current technology, a "plug and play" application of RFID technology from multiple off the shelf vendors will require significant technical troubleshooting and planning up front, with careful attention to the contents of the items to be tagged, the speed of identification needed, and the specific tracking and authentication needs.

10.1.10.3. Power Issues Limit Wireless Applications

Power is the crux of mobility. For the past decade, battery technology has remained relatively stable, with most mobile applications using rechargeable nickel-based or lithium-ion batteries. These have only increased their storage capacity at a rate of about 8-10% per year.[89] In addition, these batteries are sensitive to their environment, particularly temperature. Intermec, in Everett, WA makes hand held devices for industrial applications. They have announced plans to use a methanol fuel cell from MTI MicroFuel Cells of Albany, NY in a device intended to track inventory. Experts anticipate that full commercialization of fuel cell products is unlikely with the next five to ten years.[90]

One designer of fuel cells, Stephen Tang of Millennium Cell, has developed a boron-based fuel cell. Current cells in prototype can power a mobile phone for 12 hours talk time compared to the current 4 hours for an equivalent size battery. Even better, these fuel cells would be disposable just like today's alkaline batteries. The cell phone version will be contained in a package whose price target is $1.50 and Tang hopes to reach the market by 2005.[91]

One company, Valence Technology, Inc. out of Austin, TX, has developed lithium-ion batteries that are paper-thin and similar to plastic. These batteries can actually be molded into different shapes and are being carefully assessed by hand-held device makers.

Another futuristic development is underway at SRI, International in Menlo Park, CA. Researchers there are working on artificial muscle transducers – actuators composed of inexpensive, easily produced elastic polymer materials that can be fitted into the boot of a warfighter to produce power as the soldier walks.[92] This power would then be cabled from the boot to portable devices, thus reducing the need for batteries. Currently batteries take up approximately 10 pounds of the overall 80-100 pounds of gear carried by the warfighter.

 Perhaps one of the more interesting applications of wireless technology is the small island nation of Niue located in the Pacific. This island of 100 square miles offers an interesting opportunity to study low-power solar transmitters. Such applications may well suit the USMC in remote locations where portability is combined with erratic power systems and very remote locations.[93]

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[89] Tam, Pui-Wing, "Gadget makers join the scramble to zap the 'power gap,' *Wall Street Journal*, January 17, 2003, p. B1.
[90] Ibid.
[91] Woolley, Scott. "Cutting the other wire," *Forbes*, September 1, 2003, p. 102
[92] Prencipe, Loretta W. "Walking Power Generators," *InfoWorld,* June 2, 2003, p.53
[93] "All this and free wireless, too." *Business Week*, September 1, 2003, p. 14.

10.1.11. Recommendation for USMC Future Activities Based on Analogous Commercial Activities

Table 10 summarizes RFID and other wireless commercial supply chain activities with respect to manufacturing and logistics activities. Key attributes of the systems are included whenever data is available.

Table 10: Wireless Applications Summarized With Respect to Manufacturing & Logistics Activities

Logistics Function	Company	Wireless Application	Description	Operating Environment	Communication Mechanics	Cautionary Notes
Inventory distribution	CHEP	RFID mounted into wooden pallets to track inventory locations worldwide	RFID read/write passive tags mounted into reusable containers that are leased out to manufacturers; currently used for CHEP internal tracking of its pallet inventory; not used by its customers to track their inventories at this time	Mixed warehouse and distribution environments	Semi predictable communication between pallet-mounted RFID and fixed location readers	
Inventory distribution tracking	The Gap	RFID tagged items for in-store and supply chain tracking	RFID read/write passive tags embedded in individual items tracked at store level (incoming and sales) promotes demand forecasting and supply balancing across stores	Standard retail environment	Predictable communication between item level RFIDs and fixed location readers in retail environment	
Inventory distribution tracking	DHL	RFID tracking of in-transit phones locations in the supply chain	Delivery vehicles track RFID tagged phones	Mixed transportation to retailers	Non-predictable in-transit communication flows between RFID tagged phones and reader-mounted delivery vehicles and satellite tracking system	Real-time identification of phone theft
Inventory distribution tracking	Lionize Logistics	RFID tracking of item level inventory	RFID using UHF 915 MHz label tags (approximately 9 foot read range) to track of incoming office equipment replaces bar coding; warehouse management of inventory on site	Standard warehouse environment	Predictable communication flows between RFID tagged individual items, fixed location readers, and hand held readers	
Inventory distribution tracking	Beal Solutions	RFID tracking of reusable containers for electronics equipment	Tracking of deliveries and returns from PC manufacturers and distribution partners. Beal is a third party logistics manager	Mixed transportation to retailers	Semi-predictable communication flows between incoming RFID tagged totes, fixed location readers, and the Beal warehouse system	
Inventory distribution tracking	Tibbett & Britten	RFID tracking of small-packaged items in during distribution	RFID tagged packages of Unilevel products tracked during distribution to Safeway stores to determine exact location and manage inventory	Mixed transportation to retailers; standard warehouse environment	Predictable communication flows between RFID tagged packages and fixed location readers, linked to centralized Unilevel database	

Continued: Table 10: Wireless Applications Summarized With Respect to Manufacturing & Logistics Activities

Logistics Function	Company	Wireless Application	Description	Operating Environment	Communication Mechanics	Cautionary Notes
Inventory tracking	Revlon and International Paper	RFID item level tracking (cosmetics)	RFID read only passive tag tracking of individual cosmetics to determine when color or type is sold out and needs reordering; facilitates real-time stocking of shelves	Indoor retail environment	Predictable communication flows between RFID items and shelf-mounted reader; reader communicates with retail system	Tracking of sales data (via RFID removal from shelf) also identifies large quantity removal suggesting theft
Inventory tracking	Georgia Pacific	RFID mounted on plastic reusable containers	RFID passive read only tags (with read distance of about 10-12 feet) mounted on plastic reusable containers used to ship perishable goods from grower to retailer; containers were returned and reused	Mixed warehouse and distribution environments	Predictable communication between RFID tag mounted on container and fixed location readers	Software developed to track perishable goods throughout supply chain distribution
Inventory tracking	Raxel	RFID mounted on plastic reusable containers	RFID passive read/write tags mounted on plastic reusable containers track the status of hazardous waste contents, and after use, help the company identify cleanliness of container	Mixed warehouse and distribution environments; hazardous waste container	Predictable communication between RFID tag mounted on container, fixed and hand held readers, and the company's centralized database	Hazardous waste tracking
Inventory tracking	Gillette	RFID pallet and case level tracking of Gillette products	RFID ultra-high frequency write once, read many passive tag tracking to identify inventory sales at case and pallet levels (originally intended to have "smart shelf" item tracking, but abandoned this)	Mixed transportation to retailer; Indoor retail environment	Predictable communication flows between RFID tagged case and pallet RFID and fixed location readers	
Inventory tracking	Marks & Spencer	RFID tagged reusable trays to track fresh food location	Reusable trays are tagged with RFID read/write passive tags and associated with particular contents to track inventory through warehouse and to individual stores	Refrigerated distribution environment	Predictable communication between RFID mounted trays and fixed location readers in warehouse and in stores where readers are linked to centralized database	

Continued: Table 10: Wireless Applications Summarized With Respect to Manufacturing & Logistics Activities

Logistics Function	Company	Wireless Application	Description	Operating Environment	Communication Mechanics	Cautionary Notes
Inventory tracking	Toyota	RFID tracking of parts and completed cars throughout the South African Facility	RFID read/write passive tags to track vehicle status and location during production, and then to track the completed vehicle beyond the plant to the distribution yard in close proximity to plant	Standard manufacturing environment; outdoor distribution yards	Predictable communication flows between RFID tagged vehicle parts, RFID tagged vehicle and fixed location readers connected to centralized database	
Inventory tracking	Scottish Courage Brewery (now owned by TrenStar)	RFID tracking of beer kegs throughout the supply chain	RFID read/write passive tags to track of reusable containers (kegs) throughout the supply chain	Standard manufacturing environment for filling of keg; mixed transportation to retailers	Non-predictable communication flows (location) between RFID tagged beer kegs, fixed and hand held readers, and company central database	RFID used to track keg location, including associating keg recovery with initial billing to identify black market sales.
Inventory tracking	Owens & Minor	RFID tracking of medical equipment at fixed location	RFID tracking of medical and surgical supplies at hospitals and within its own distribution center to identify location	Indoor operating environment	Semi predictable communication between RFID tag and centralized database; not known if fixed location readers are combined with hand held	
Inventory tracking	Avail	Wireless barcode tracking of aircraft parts	Bar code labels of individual bins of parts are tracked with wireless scanners and data is transferred to ERP system	Indoor warehouse conditions	Predictable communication patterns between bar code, scanner and ERP database	
Inventory tracking	ABF Freight	Wireless linkages to track in dock and in yard activities	Nextel micro browsers keypads are used to enter information that is directly uploaded into the ABF mainframe	Indoor operating environment	Semi predictable communication between individual operators and centralized database	
Inventory tracking	ES3 LLC	Wireless tracking of tractor locations in shipping yard	Using WhereNet software to track to location of trailers in distribution center yard. Contents of trailers are tracked with bar codes, not RFID. Centralized software links each trailer to its contents (as contrasted to Alien Technology active tag approach)	Outdoor operating environment	Predictable communication between each trailer slot and the centralized database	

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Continued: Table 10: Wireless Applications Summarized With Respect to Manufacturing & Logistics Activities

Logistics Function	Company	Wireless Application	Description	Operating Environment	Communication Mechanics	Cautionary Notes
Inventory tracking	O'Reilly Autoparts	Wireless web-based communication between company and suppliers	Inventory tracking using bar codes linked to web-enabled devices to track inventory, including forecasting	Standard indoor warehouse operating conditions	Predictable communication patterns between suppliers and company's centralized supply databases	
Inventory tracking/ERP	Staples	Web enabled access to ERP with multiple features	Company uses web interfaces to track inventory, demands, customer credit card authorization	Indoor retail operating conditions	Semi predictable communication between company databases, devices, and external databases; devices include hand held tablets linked to the web for sales associates	
Inventory tracking/Order fulfillment	Perishable Distributors of Iowa	Voice activated system	Inventory fulfillment in refrigerated conditions using voice-activated instructions provides hands-free for workers	Refrigerated production conditions	Semi predictable communication between individual operator and company's centralized servers	
Inventory tracking/production	International Paper	RFID item level (large paper rolls) tracking during manufacturing & warehouse storage	RFID read only passive tag tracking of location of paper rolls during production and storage within the plant	Harsh manufacturing environment with high humidity and dust	Predictable communication between RFID tagged paper roll, forklift-mounted reader, fixed location RFID in manufacturing floor, and centralized plant database	Harsh operating environment where forklift movements and location are tracked within a warehouse environment
Maintenance & Operations	SKF	Wireless transmission of vibration and rpm	Wireless transmission of vibration and rpm data on machines in operation transmitted to Machine Analyst software	Standard and field operating conditions for equipment	Semi predictable communication from machine to centralized data analysis software via e-mail; can also use other portable devices for data capture	
Maintenance & Operations	Sears	Wireless transmission of work schedules	Service technician trucks equipped with multiple communication methods facilitate mobile scheduling of maintenance staff; matching job needs to staff skill sets.	Indoor and outdoor operating environments, not anticipated to be extreme	Predictable communication channels between centralized call center and technicians	Maintenance needs matched to technician skill set automated by software**

** NOTE: a similar system also being used in Iraq for situational awareness not maintenance

Continued: Table 10: Wireless Applications Summarized With Respect to Manufacturing & Logistics Activities

Logistics Function	Company	Wireless Application	Description	Operating Environment	Communication Mechanics	Cautionary Notes
Manufacturing	Goldwin Sportswear Europe	RFID item level tracking during manufacturing, shipping and distribution	RFID read/write passive tagged skiwear is tracked during production for batch number, color, size and distribution details; production status is tracked and item continues to be tracked to distribution at logistics center (in Japan); Readers at Italy location verify incoming shipments	Standard manufacturing and warehouse environments	Predictable communication flows between RFID tagged items and fixed location readers communicating with Japanese logistics system and with Italian logistics system	Traceability of individual items enables company to track theft and counterfeit products
Manufacturing	Johnson Controls	RFID tagged seats during manufacturing	RFID read/write and read only passive tags track manufacturing needs for individual car seats; read only tags provide instructions of testing requirements	Dirty and abrasive conditions on manufacturing floor	Predictable communication between the seat mounted RFID tag and fixed location readers at production stations and testing stations	
Manufacturing	Nestle	RFID tags attached to reusable trays that transport confections	RFID is used to monitor tray hygiene and cleaning using real-time date and time stamping; trays also tracked during production to determine weights of contents	Standard manufacturing environment	Predictable communication between RFID mounted trays and fixed location readers linked to Nestlé's central operating system	
Manufacturing	Michelin	RFID tags mounted to carrier bins and hooks throughout manufacturing plant	RFID active read/write tags placed on carrier bins identify next manufacturing stage for contents; tags are reused for new production runs (note company is evaluating passive tags for this application)	Standard manufacturing environment	Predictable communication flows between RFID mounted bins and fixed location workstation mounted readers	
Manufacturing	Maldin Mills	RFID tags used to locate imperfections in manufactured Polartec fleece	RFID read only passive tags are placed on imperfections identified during inspection of large pieces of manufactured fabric. Tags alert slitting machines to halt for human intervention in fabric location; tag is removed from imperfection and reused	Harsh manufacturing environment	Predictable communication flow between RFID tag and reader which is mounted on the slitting machine	Harsh manufacturing conditions require special tag casing

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Continued: Table 10: Wireless Applications Summarized With Respect to Manufacturing & Logistics Activities

Logistics Function	Company	Wireless Application	Description	Operating Environment	Communication Mechanics	Cautionary Notes
Manufacturing	Toyota	RFID tracking of car frames as they move through paint stations	RFID read/write passive tags capture vehicle number, model number and paint color to direct the paint robots along predetermined paths with the correct paint color	Standard manufacturing environment for painting, but intense heat environment in paint oven	Predictable communication flows between RFID tagged frame carrier, centralized database, and fixed location readers lined to paint robots	Extreme heat requires special casings for the tags, increasing price of each tag
Manufacturing	Harley Davidson	RFID tracking of custom motorcycle manufacturing	RFID read/write passive tags capture the serial number of each custom bike and readers at each assembly location give instructions as to next step in assembly	Standard manufacturing environment	Predictable communication flows between RFID tagged bike frame carrier bin, fixed location readers at the employee workstation, and the company's data system which contains the instructions for custom assembly	
Manufacturing	Ford	RFID tracking of engine manufacturing	RFID read/write passive tags track the date and time that each stage of engine manufacturing is performed to develop a history for each engine	Standard manufacturing environment	Predictable communication flows between RFID tagged engine carrier bin and; fixed location readers, and centralized Ford plant database	
Manufacturing	Boeing	RFID tracking work-in-process parts	RFID UHF 915 MHz read only tagged parts tracked during work-in-process to identify next manufacturing/assembly step; manufacturing record remains linked to part to document part integrity	Standard warehouse environment	Predictable communication flows between RFID tagged parts and fixed location workstation-mounted readers communicating with centralized plant documentation system	Part integrity determined by unique RFID identifier tied to manufacturing stages
Point of Sale Payments	ExxonMobil	RFID enabled debit system in embedded hand held transponder	RFID read only passive tags mounted in hand held transponder tracks purchases of gasoline acting as a debit card	Mixed retail environment	Predictable communication between hand held RFID transponder and fixed location readers linked to centralized credit card authorization system	

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The breadth of systems available and in use in commercial logistics activities spans a wide variety of applications. From an asset visibility perspective, wirelessly enabled scanners combined with bar codes or RFID tags and readers are needed. Either of these two approaches must be tied to a centralized database to link the limited information that can be accommodated on the bar code or RFID tag with additional information about the contents of the item, case or pallet.

The following recommendations are divided into four categories: (1) Communications; (2) Use of bar codes and RFID; (3) Operational changes; and (4) Implementation issues.

10.1.11.1. Communication Recommendations

1.   Plan redundancy of communication channels into system, particularly those channels that link into centralized data. Communication linkages must have redundancy built into them, particularly if they are to be effective in non-garrison environments, so that critical item identification and tracking is not lost with communication disruptions. It should be noted that loss of communication is a problem that has been noted as causing difficulties in the implementation of wireless and/or RFID systems. When communication links are down, there is little that the operator or inspector can do to identify the package or item.   This further reduces visibility in the supply chain.   Though communication disruptions are not as common in fixed locations that share wireless and hardwired channels, in a fully mobile environment this will be a key issue.

2.   Only adopt wireless applications where mobility is essential. Though every aspect of a logistics chain can be wirelessly enabled, some of these nodes do not benefit from wireless, or are too remote to be able to effectively link into centralized systems to fully utilize information. In addition, in the USMC theatre environment, potential targeting of wireless transmissions must be balanced against possible benefits to wireless communication.

10.1.11.2. Use of Bar Codes and RFID Recommendations

 Use bar codes for the following:

   1. **Items that can easily be scanned manually.**

   2. **Items that must be scanned manually due to some material or other consideration.**

Use read-only passive RFID for the following:

1. **Items that will never change their contents and which do not need to have additional information associated with them during transit.** These should be used for items that can easily be scanned by an RFID reader in a fixed location.

2. **Use read-only passive RFID tags to track critical equipment within a fixed location** (such as medical equipment being tracked within a hospital location or key maintenance equipment that might be shared among workers).

Use read/write passive RFID tags for the following items:

1. **Items that will not change their contents, but which may have additional temperature, time or other tracking recorded during transit.**

2. **Items whose contents may change during transit.** This might include pallets whose contents may need to be modified as items are removed and delivered in transit.

The trade-off between fixed location and mobile (hand-held) RFID readers:

1. **Use fixed location readers whenever accuracy is needed (with little or no manual backup)**

2. **Use mobile (hand-held) RFID reader when mobile scanning is essential and when procedures are put into place to verify the reads in some way.** Hand held devices are much less reliable (as low as a 78% read accuracy compared to 99% read accuracy of fixed location readers). The use of mobile devices must be carefully considered.

3. **Use mobile (hand-held) bar code scanner when contents of bins or other larger containers needs to be tracked; consider voice activated pick-and-pull inventory for complex combinations of smaller items, or in environments where hands-free is important.**

Carefully match item content, material composition, RFID tag protocol and reader hardware to ensure compatibility. Some items that will be tracked, as well as their packaging, will interfere with or distort RFID signals, thus reducing read efficiency (time to read) and accuracy (correct content). Pilot trials have determined that tags and readers are not interchangeable. Although this is the desired goal through standardization, it is not currently achievable.

Reusable containers should be RFID tagged in the following way:

1. **Use passive read-only RFID tags for reusable containers that will only contain one type of hardware (a specialized container).** This tagging can help locate the containers across the logistics chain, thus reducing damage to critical equipment that must be packaged in specific containers.

2. **Use passive read-write tags for containers that have instructions associated with them for handling, manufacturing of contents, or for cleaning.**

3. **Use passive read-write tags for containers that will have their contents associated with the tag.** Some containers have their contents directly associated with the tags; others have their contents associated with a centralized database that can be updated. For containers that will have their contents associated with them, use passive read-write tags to modify contents as it changes during transit.

Anticipate multiple tagging of items and modified pallet handling. Tests have shown that multiple RFID tags on a single item improve read efficiency and accuracy. In addition, placement of RFID tags may differ from traditional line of site bar codes. Norfolk has discovered that pallets must have a more circular shape to improve read efficiency and accuracy. These should be planned into the implementation.

Item level, case level and pallet level tracking.

1. **Consider item level RFID tracking for large, complex items with high value.**

2. **Consider case level tracking for groups of relatively high value of items and/or for items that must have additional data associated with them (temperature, time, humidity or other factors that might degrade performance).** This might include perishables and medical supplies, as well as equipment that is sensitive to heat or humidity.

3. **Consider case level tracking for multi-content shipments that will need to be distributed (broken up) during transit at multiple staging areas.**

4. **Consider pallet level tracking for relatively low value items that can be shipped in bulk or that will not need to be broken down multiple times during transit at multiple staging areas.**

10.1.11.3. Operational Change Recommendations

Semi-passive tags must be carefully deployed. Semi-passive tags are battery assisted to improve read-range. However, batteries degrade in severe heat and so these tags introduce additional monitoring needs into any system to make sure that the batteries are in working order. The read-range boost must be considered in light of this additional monitoring.

ERP system linkages will require web-based service oriented architecture. The commercial system is going away from monolithic software solutions to modular solutions connected together with web services. Any USMC configuration should plan for this emerging flexibility.

10.4 Implementation Issue Recommendations

Anticipate some human-in-the-system interaction for any RFID system (at least in the near to mid-term). Early pilots, particularly at Norfolk Ocean Terminal, suggest that human intervention will be needed to verify and validate RFID reads. Though RFID reduces time to read, accuracy must be checked, sometimes manually.

Anticipate possible monitoring of RFID exposure for personnel working with the systems. Though RFID has not been proven clinically hazardous to human health through exposure, this issue continues to concern workers associated with the systems. Workers at Norfolk, for example, questioned the safety of working within these environments.

Anticipate communication channel changes with the introduction of wireless systems (beyond those built into the system). Experience shows that systems co-evolve. With the introduction of any wireless or RFID system, workers will begin to modify their former behaviors and to build new informal communication channels. Unfortunately, the wireless or RFID systems are frequently built on the workflow processes in place or anticipated. Systems such as these change the way that information flows, particularly its direct flow to lower levels in the organization. Workers at these lower levels, now informed, are apt to take on more decision-making activities. This may be in direct conflict with traditional command and control structures of the military.

Anticipate significant investments in middleware software for full system functionality. Currently ERP systems and middleware offer solutions to data exchange and transfer, but commercial experience shows that these linkages are often not robust enough and thus, further investments in customization of software have been required. Careful discussions with vendors will help identify tracking needs and customization required.

Anticipate a difference between garrison activities and in-theatre activities with respect to RFID and bar code uses. Current hand held readers are not as robust and procedures that work for fixed location readers (in garrison) will not necessarily work equally as well in the field with hand held readers. Some human in the system intervention or additional checking/monitoring of ID reads will be required in the field with hand held readers.

Consider use of RFID/bar code printers. To facilitate multiple types of reads throughout the supply chain, printers that generate a single bar code label with an embedded RFID code might be a practical solution to relabeling in transit.

For combined communications on a single platform, a closer look at the Itronix system developed for Sears and others for remote maintenance that has been adapted for use in theatre in Iraq currently by DoD is advised. Before creating a unique system, the USMC should review the current Itronix system in Iraq for possible use in logistics and communication. This system has been developed from a commercial application platform, but with robust features added to address the harsh operating conditions in the field. Though the Sears system and other commercial applications are using the Itronix system for real time maintenance workforce scheduling, the configuration might prove useful to USMC needs.

Develop an RFID tag deployment plan before implementation. Some vendors offer RFID 'boot camp' to help planners anticipate needs and uses; others offer starter kits to help planners develop pilot implementations. Regardless of the start path, thought should be given to the roll out of RFID since it will have implication for the middleware needed at particular stages, the trouble shooting to anticipate, the robustness of the redundant communication channels and software, and the human-in-the-system needs. If all is not in place prior to rollout, system performance will be degraded if commercial implementations are any guide.

10.2 Proof-of-Principle Implementation

This section gives the details of the different scenarios that were identified and the proof-of-principle system that has been developed.   The later sections provide details about the user interface process flow and the relevant databases that were developed.

Scenario 2:

Figure 9.2.1 shows the information and physical flows when the part is not available within the CSSE Det but is available at FSSG.
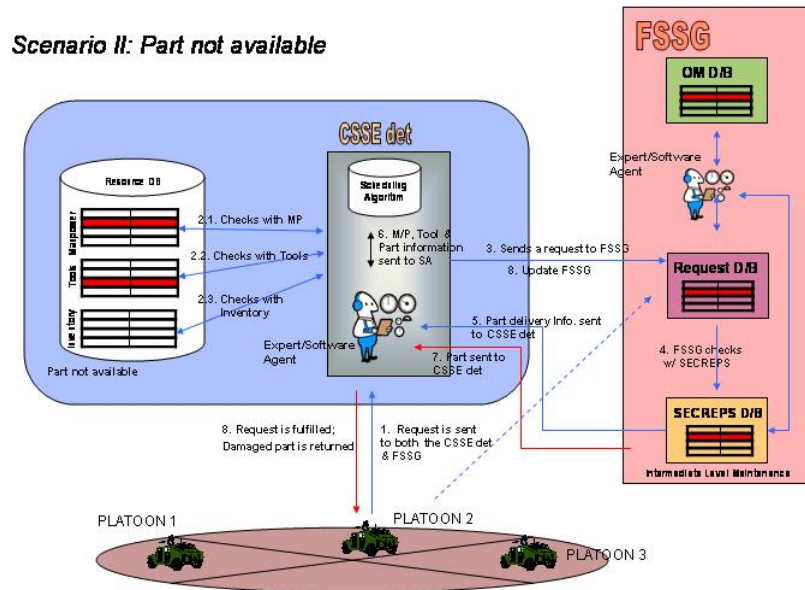

Figure 9.2.1: Part – Not Available

Scenario: 3 and 4

The scenario in Figure 9.2.2 shows the sequence of events when the part is not available at the CSSE Det and FSSG. The FSSG places an order for the part and also broadcasts the request for the part to the neighboring CSSE Det. If the part is available within a neighboring CSSE Det, it is sent for fulfilling the request. The FSSG replenishes the part at both the CSSE Dets. If none of the CSSE Dets have the requested part, then the FSSG places an order for the requested part. Once this part is procured, it is sent to the requesting unit. This leads to Scenario 4 shown in Figure 9.2.3.
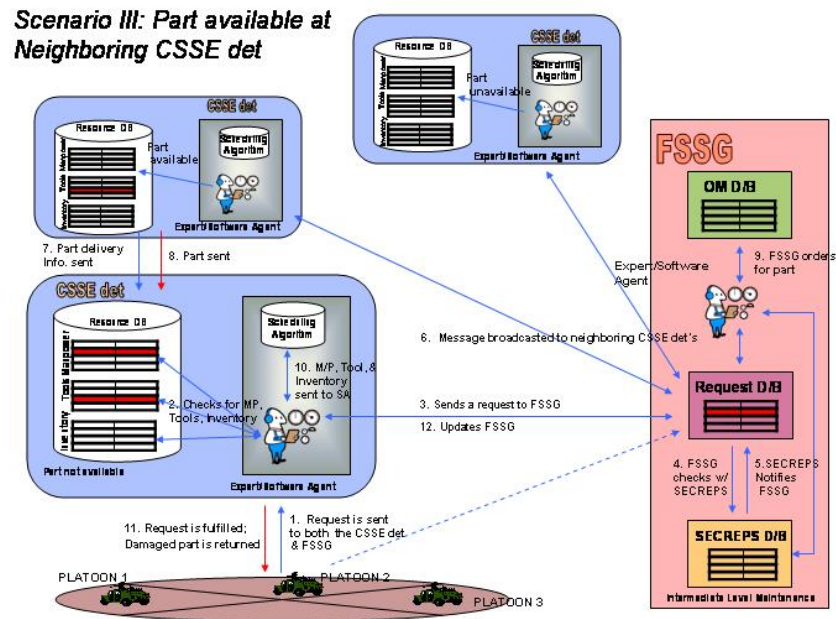
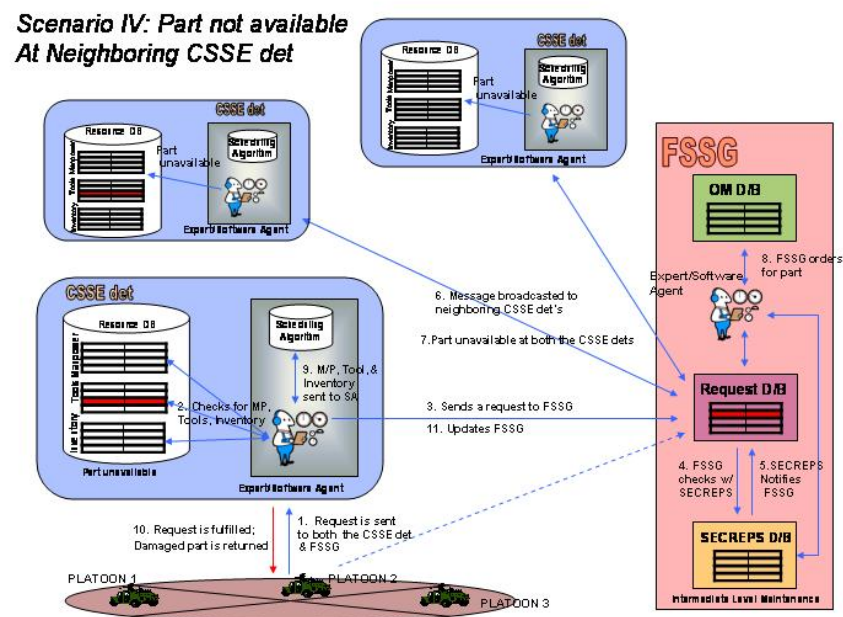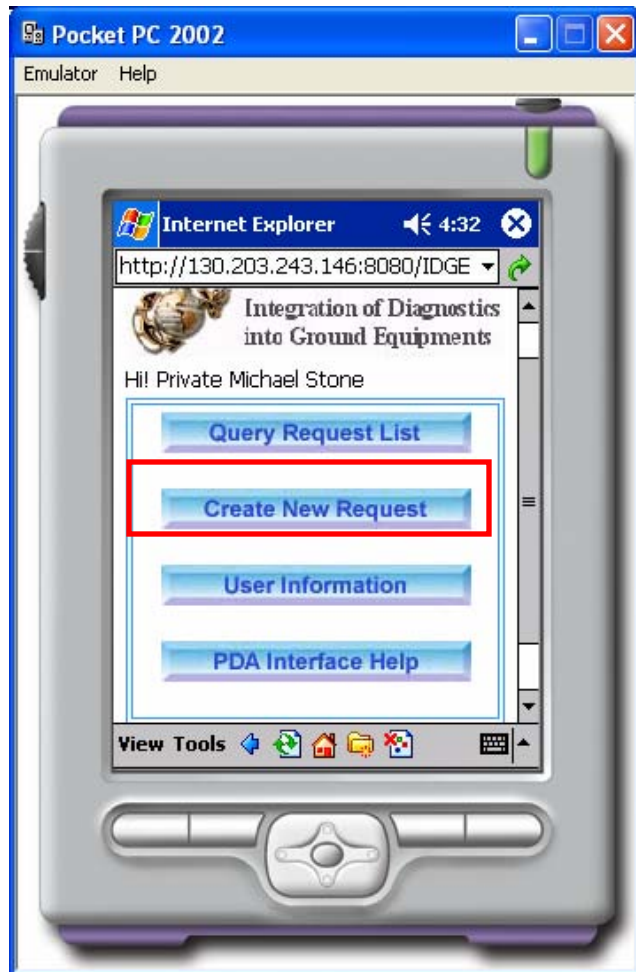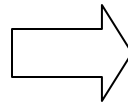**Figure 9.2.2: Part Available at the Neighboring CSSE Det**

Figure 9.2.3: Part Not Available at the Neighboring CSSE Det

The following are the PDA user interface showing the flow of information for maintenance scheduling.[5]
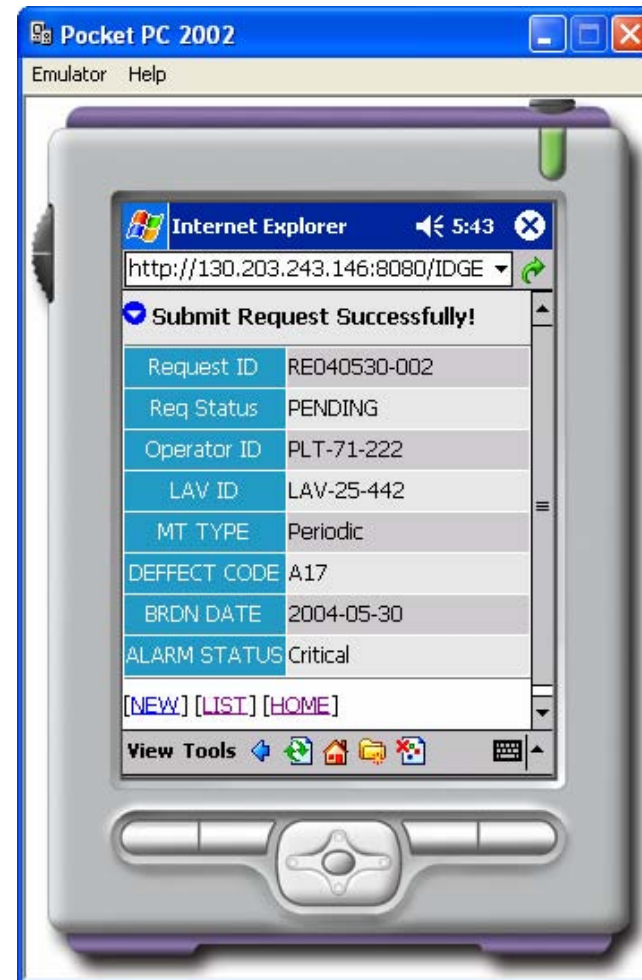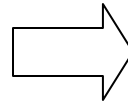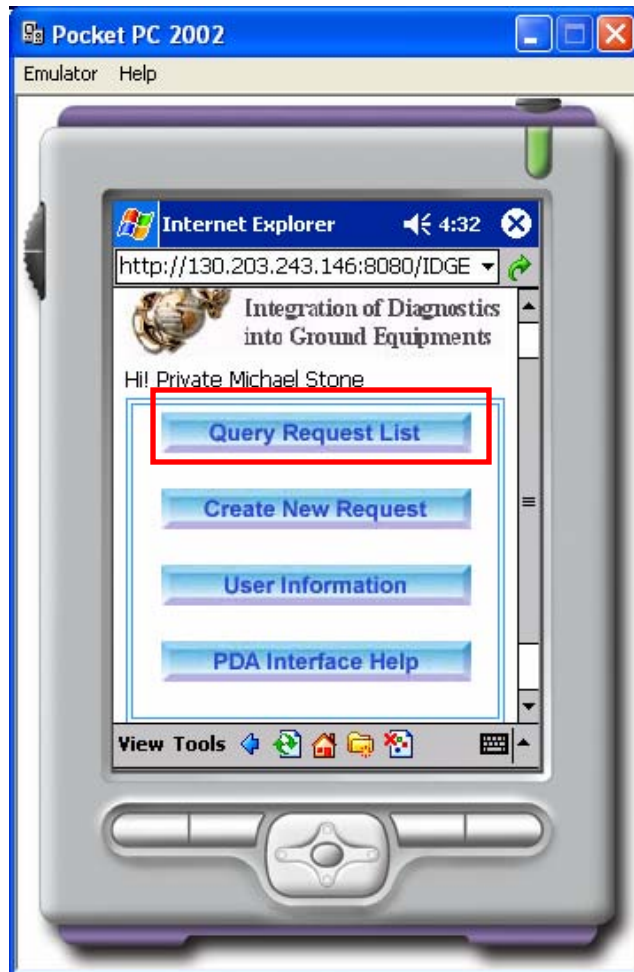
Operator creates new maintenance request.

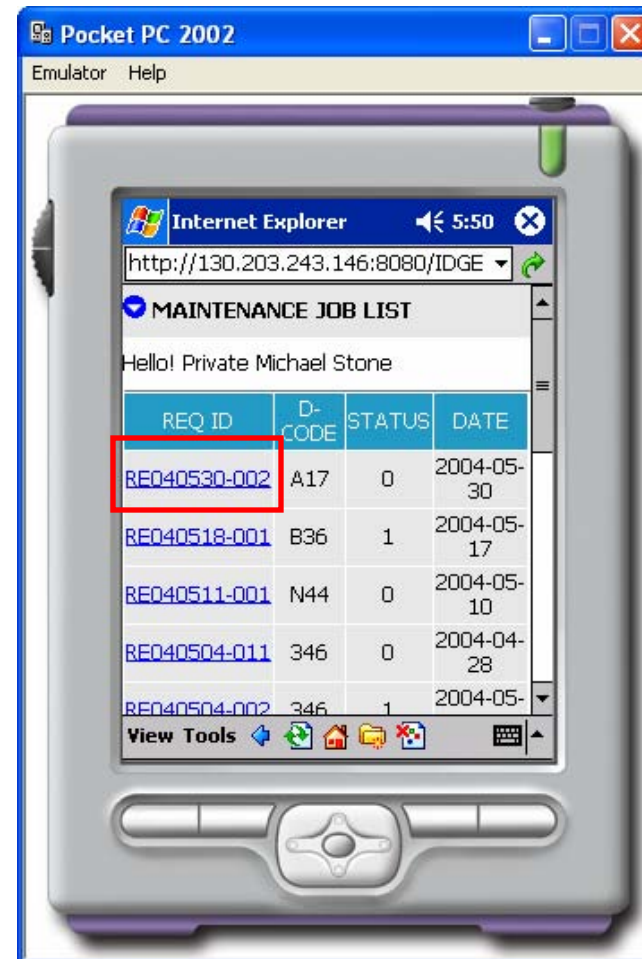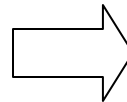Details for new request are filled in.

Request Submitted.

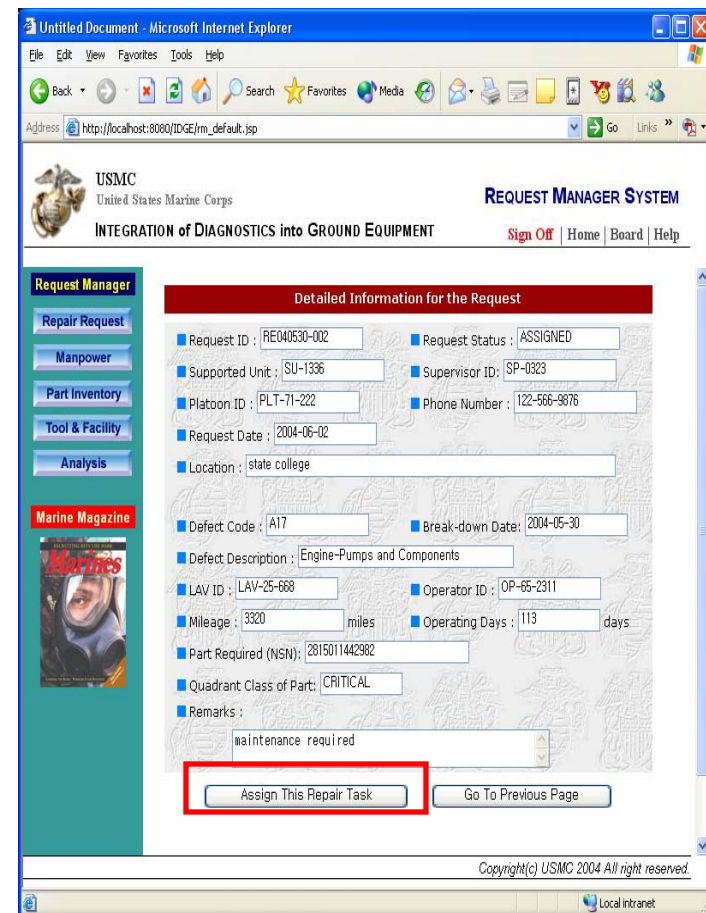Receives confirmation of request submission.

Queries the list of Request that have been sent and checks for update.

Newly created request has been updated within request list.

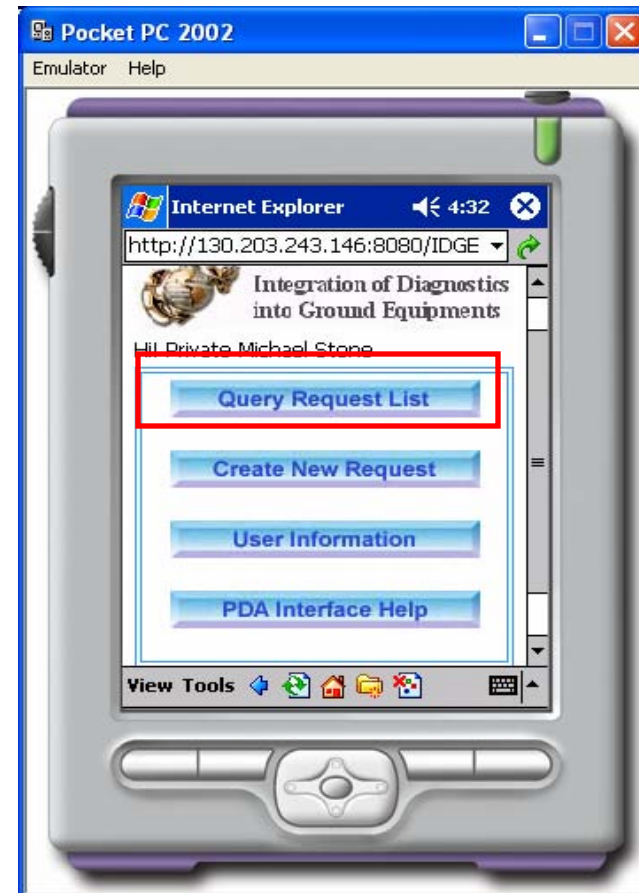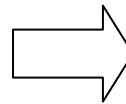Views the detailed information for the submitted request.

Request received at RM and resources are assigned.

The mechanic logs on to the system using PDA.

Use the query request list option to view the tasks that are assigned to him/her.

The maintenance job list shows the maintenance task has been assigned to Private Michael Stone.

The operator is notified that the resources for the request have been assigned.

Database

Data Model Diagram

This diagram shows the connectivity between elements of the tables listed in the Figure 9.2.4.

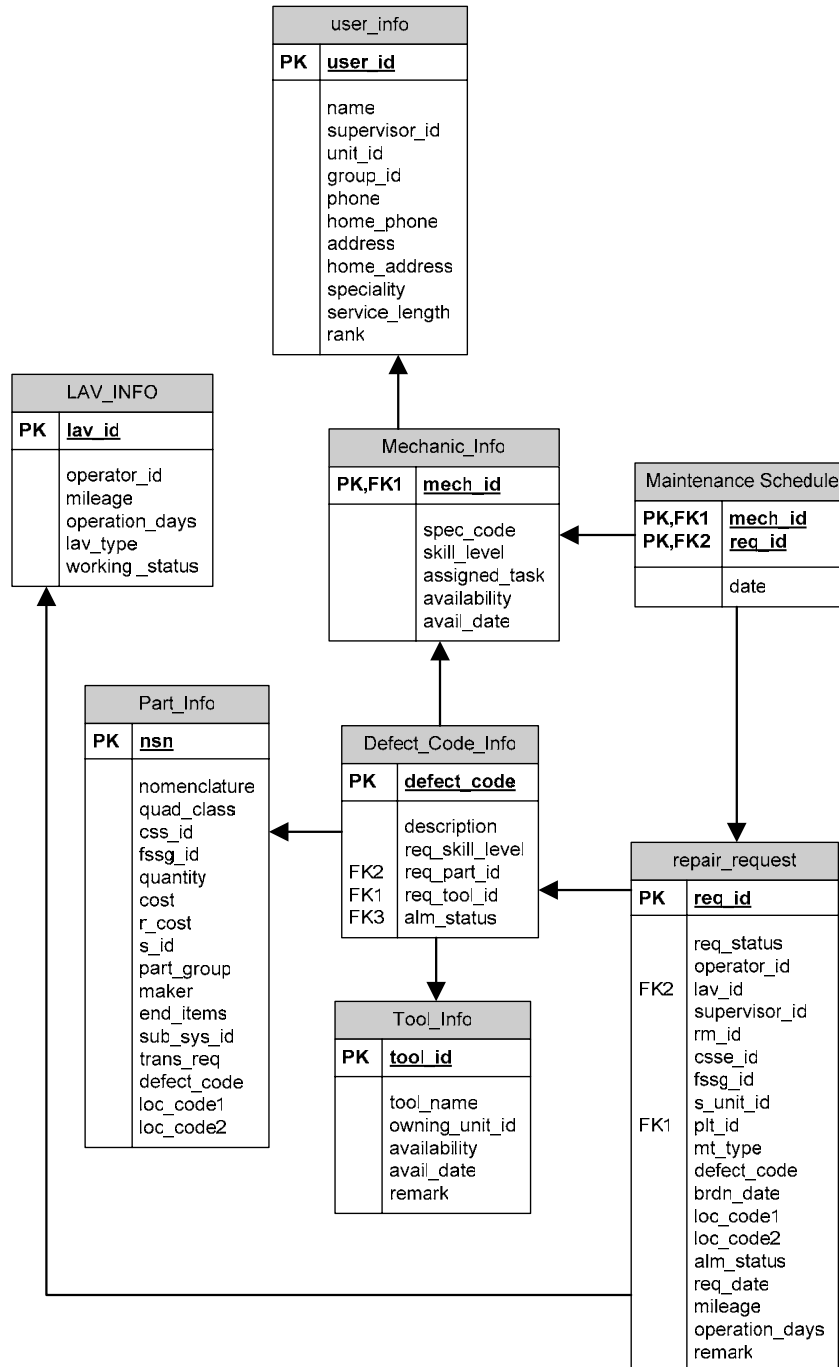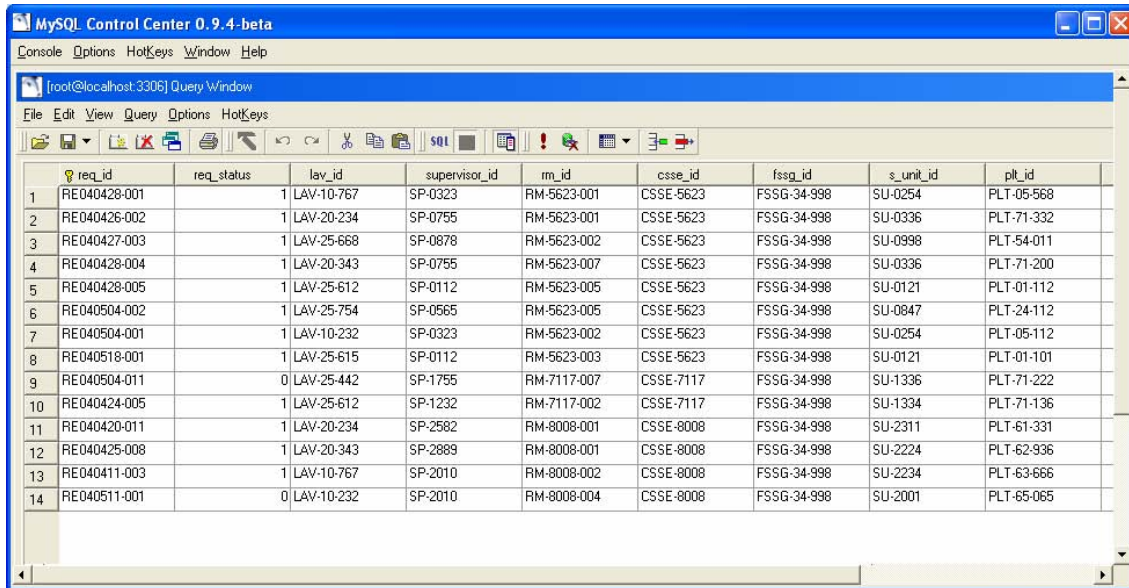**Figure 9.2.4: Data Model Diagram for the Proof-of-Principle System**.

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Main Database for Implementation: The following are the database tables developed for the proof-of-principle system implementation.

- Request Maintenance Table

- Maintenance Schedule Table

● Part Information

● Mechanic Information

● Tools Information

10.3 *Interim Report 1*

10.4 *Interim Report 2*

10.5 *Interim Report 3*

PENNSTATE
1855

Marine Corps Research University

Interim Report 1

Enabling Logistics with Portable and Wireless Technology Study

AUTHORS

The Pennsylvania State University, University Park, PA 16802
School of Industrial Engineering
  Dr. Soundar Kumara
  Dr. N. Gautam
Pennsylvania Transportation Institute
  Dr. Zolton Rado
  Dr. Robert Gray
School of Information Sciences & Technology
  Dr. Dave Hall
  Dr. Irene Petrick
Project Manager: Col. Barney Grimes, US Marine Corps

MCRU PROGRAM MANAGER

Lt. Col. Ron R. Madrid, USMC (Ret), Penn State University

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1.0 Introduction

The current study is intended to assess the possible use of wireless technology to facilitate USMC logistics, including both battlefield and garrison. Parallel to this effort is a much larger USMC effort to rationalize its end-to-end logistics processes so that the battlefield configuration that uses a single point of contact mechanism (S1) to route requests to other suppliers (Sn) could be adapted to garrison operations. This will require both procedural changes in end-to-end logistics processes as well as personnel issues.

The USMC is using the Supply Chain Operations Reference Model (SCOR Model) to guide its reengineering activities. Because of this, many of the SCOR principles will be considered in the current study. The development and assessment of metrics to judge whether or not improvements are indeed achieved by reengineering efforts will be of interest. Some of the same principles will be applied to determine whether or not a transition to wireless is advised for individual activities. <u>Thus, a guiding principle of the current PSU wireless study is that although wireless options exist, they may or may not be better from a performance standpoint, or prudent from a safety standpoint. Efficiency of communication and safety will be paramount considerations.</u>

The PSU wireless study includes six tasks:

1. Background Research and Review OA Processes and Performance Measures
    i. Assessment of USMC-provided reference materials for intended Logistics OA
    ii. Review of on-going DoD wireless technology initiatives
2. Conduct Market Research and Recommend Processes to be Enabled
    i. Market survey of COTS and future wireless technologies adaptable to the OA
    ii. Identification of OA processes that might benefit from wireless technologies, including identification of possible metrics to assess benefits

3. Identify Key Data Elements and Information
4. Determine Unique Military Considerations
5. Determine Feasible solutions
6. Determine Impacts of Implementation

1.1   Discussion of Tasks

Task 1.1 – The first two months of the PSU wireless project have been consumed trying to understand the USMC's reengineering goals and objectives, and to assess the impact that this reengineering effort will have on the flow of goods, people, and

information across the end-to-end Logistics chain. The research team relied on materials supplied by the USMC about its intended Operational Architecture (OA). Since Penn State is a member of the Supply Chain Council, full SCOR documentation has been downloaded and is currently being reviewed to determine the implications of SCOR Level 4 logistics support needs. Level 4 metrics will need to be developed to determine how to judge the efficacy of a wireless versus a more traditional solution to information transfer.

Specific process elements must be identified (SCOR Level 3). These must then be assessed in the framework of wireless versus traditional technologies. The PSU wireless study is a companion effort to an ongoing PSU activity to model Light Armored Vehicle (LAV) maintenance and logistics needs to support Condition Based Maintenance (CBM) and Autonomic Logistics (AL). Using these two methods, the intent is to automate as much of the anticipatory maintenance to increase logistics chain effectiveness. The PSU wireless activity will build upon the LAV logistics activity as a way to demonstrate the impact that wireless might have in facilitating data transmission and supply chain effectiveness.

The research team is aware of COTS solutions to wireless based communications. In particular, we will concentrate on technologies using Iridium cluster of satellites.

Task 1.2 – Little has been done on this task since additional information about other DoD wireless activities has not been communicated by USMC personnel. The research team is aware of a Joint Strike Fighter (JSF) logistics chain initiative that may facilitate comparisons; however, contact with the appropriate JSF personnel has yet to be established. Additional information is needed to assess what wireless activities are occurring in other branches of the military, for example.

Task 2.1 – A wireless Communications report have been developed by the team members. The Wireless Communication report summarizes wireless telephony, wireless data networks, wireless data transmission systems, switching mechanisms, and touches on emerging wireless technologies. Additional work will need to be done for the remainder of the PSU wireless study to update this first pass at a literature review. Particular attention will be paid to the use of wireless solutions within logistics chain activities, regardless of their context.

As part of this task it would be helpful to have a more complete understanding of the USMC infrastructure to support wireless communications. For example, what options, including Iridium, is USMC using and/or considering for future use. This may constrain options for transmission and receiving.

Task 2.2 – Identification of those processes that might be most amenable to wireless technology lies at the heart of this Penn State study. Because of this additional time must be spent to develop an understanding of the USMC intended reengineering of its logistics chain. There are several issues that arise, including

- Though the USMC wishes to develop is OA so that garrison operations more closely parallel battlefield communication patterns, there are limitations imposed on the battlefield that do not exist in garrison. This is particularly true in the area of wireless technology and transmissions. For example, wireless transmission of data on the battlefield also serves to pinpoint the location of the transmitter for those monitoring transmission channels. Despite encryption, this locational pinpointing of potential targets must be balanced against the improved efficiency of wireless battlefield communications regarding logistics chain activities.

- Battlefield operations necessitate focused cognitive efforts of participants. Any wireless technology must also consider the multi-tasking environment and balance the transmission speed and ease with other warfighter tasks. Even though human factors and human-computer interface (HCI) issues are not specifically part of the current PSU wireless study, these issues will be considered,   if   not   fully   resolved.

- As part of SCOR, consideration will be given to those tasks within the logistics chain that are routine, bottlenecked, leveraged or critical. The effectiveness of wireless transmissions will be considered with respect to the need of the requisitioning,   transmitting   or   responding   entity.

- For possible wireless technology implementations in the logistics chain, the study will consider the request for and provision of supplies and services; the movement of people, and the actual transmission of data. Because of this, attempts will be made to separate make-to-stock, make-to-order, and engineer-to-order products. In addition, distinction will be made between routine maintenance, immediate maintenance and priority maintenance. This is further complicated by the differences in priority levels in garrison and on the battlefield. Wireless technology on the battlefield will need to have reduced complexity compared to garrison, and this will depend on bandwidth available.

Further discussion with USMC personnel and other Penn State researchers is needed to determine what might be instrumented, the rate and amount of data flow and the nature of the data flow. The PSU wireless project is concerned with the full scope of the USMC logistics chain. However, we will concentrate on maintenance to detail many of the infrastructure development activities and technology assessment. In general, a second guiding principle of this study follows Occum's Razor – simplicity is preferred to complexity in wireless transmission.

Task 3 – Based on the OA that emerges, the team's understanding of current, emerging and future wireless technology, and the team's understanding of garrison versus battlefield operations, Task 3 will suggest specific information needs to accomplish wireless transmission. This might include the collection and transmission of new or existing data; the reconfiguration of data to simplify

transmission; and suggestions for possible reformulation for further processing through the logistics chain. This task has yet to be addressed.

Task 4 – This task is really, what separates traditional logistics operations, potentially incorporating wireless data transmission, with the realities of the USMC and its operations. The research team will focus its next two months on this task. Specifically, the researchers will seek to interview USMC personnel and to review documents about the realities of battlefield operations. USMC experiences in recent engagements in Bosnia and Iraq might offer some input about current and future battlefield needs (and thus implied logistics chain needs, priorities, and safety issues). In addition, governmental procurement procedures that constrain USMC streamlining of its logistics chain must also be considered.

Tasks 5 & 6 – Tasks 1 through 4 must be completed prior to identifying feasible solutions and determining their impact. Still to be determined through discussions with the USMC personnel are the mechanics of determining the impact of wireless implementation. For example, will the research team be required to simulate data or will the USMC provide data? Also though the study will aim for SCOR Level 4 detail, the data must be robust enough to actually accomplish this. Simulated data, particularly if based on many simplifying assumptions, will limit the team's ability to reach Level 4 metrics with confidence. These issues will need to be addressed in the next three months.

2.0   Background Information

Most of the material in the section is a reproduction or summarization of the two documents [1] and [2] mentioned in the references.

2.1 ULAS: A Summary

Unit Level Ammunition Status (ULAS) project aimed at developing a capability to establish and maintain daily ammunition stock levels by individual Department of Defense Identification Code (DoDIC) using Commercial-Off-The-Shelf (COTS) technologies.   This capability must allow timely aggregation of multi-level ammunition stock status, and improve ammunition logistics situational awareness and Joint munitions status reporting (MUREP).   The envisioned ULAS proof-of-concept does not eliminate current processes but however shift the domain of the process from labor-intensive pencil-and-paper methods to processes based on portable computing, satellite communications, and copper wire.   The simplicity of the ULAS technology, its ease of use, its relative low cost, and its likely applicability to a wide spectrum of commodities and other resources make it an alternative to the current methods.

Current systems and processes:

The current process for collection, aggregation, and reporting of ammunition status is predominantly manual.   At the small unit level (battalion and below), it might take the form of an informal handwritten message, a notebook sheet, scraps of paper, or use of voice media such as radio and tactical telephones.   At each succeeding level of command, the process becomes more complex due to the need of aggregation of the reports for multiple subordinates, and includes the assets for self.   At these levels and higher some automation exists in the form of spreadsheet applications, primitive database applications, and a DOS-based application.   There are no electronically report assets into these systems.   All inputs are manually processed and analyzed in the context of the data are stored in.   Moreover, the output from these systems is also essentially manual since there are no formal interconnections with other logistics support tools.

Project Goals and Objectives:

The goals for the ULAS Pilot Project were to demonstrate that it is technically feasible to accurately establish and maintain ammunition asset visibility at levels below retail, and that the collected data, combined with information from accountable records, may be used to provide a wide array of ammunition logistics information for the commander.   It was also the intent to demonstrate a capability to extract and report information that is relevant to the Unified

Commander's Munitions Status Report (MUREP). The ULAS pilot project were to reduce the time required to collect and present ammunition asset information, standardize the methods and processes involved in collection of the information, and as a derivative objective, to extract relevant information for preparation of the Service Component commander's portion of the MUREP.

Pilot lessons learned:

The ULAS Proof-of-concept development and demonstration provided a number of lessons learned. They are:

i. The Iridium modem technology, combined with a Portable Electronic Device (PED), was demonstrated to be an extremely robust medium for quick communications form almost anywhere in the world.

ii. The infantry battalion, and similar or smaller sized units operating independently, can be provided with a lightweight ability to communicate their logistics or operational information to command elements for information or action as appropriate.

iii. Collecting and reporting only Essential Elements of Information (EEI) on the PED, and reserving the major share of the analytical work to the server can generate significant efficiencies. These efficiencies are manifested most obviously in the user's perception of simplicity of the tool, and in conservation of battery life- an important logistics consideration. Intuitively, since the ULAS, as designed, works outside tactical data network it should also create potential for a net decrease in demand on tactical bandwidth.

2.2 EMSS: A Summary

Joint Functional Area:

Electronic Maintenance Support System (EMSS) is a decision support tool required in USMC (fully operational capability FY 08) to take advantage of the capabilities of Interactive Electronic Technical Manuals (IETMs) in diagnostics and to eliminate the printed technical manuals which bridges the gap between Computer Based Training (CBT), Built In Test/Built In Test Equipment (BIT/BITE) and the Marine Corps Family of Automated Test Equipment (MCATES) and other related programs. The EMSS will also provide ground maintenance personnel an electronic decision support tool that will reduce repair cycle time and the removal/replacement of non-faulty parts, improve the BIT/BITE capabilities of weapon systems, impart experience and technical information on the job, and significantly reduce the reliance upon paper publications. The EMSS will serve

both in garrison and tactical environments as the principle maintenance aid for Marines.

Capability Gap:

In September 1985, the Secretary of Defense signed a memorandum titled Computer-Aided Logistics Support (CALS); the goal of CALS was the digitization of acquisition logistics products to include technical manuals, training material, technical data packages, and product definition data. Later in the year 1993, CALS was renamed as Continuous Acquisition and Life-cycle support.

New systems developed/developing by the commercial industries rely heavily on the abilities of IETMs and /or the extraction of equipment health information from onboard computers to assist in the rapid diagnosis of equipment faults and the subsequent repair action. Digitalizing technical data will significantly reduce the Mean Repair Time (MRT) by improved diagnostic accuracy.

EMSS will considerably reduce the logistics requirement to transport a failed system to rear echelon maintenance facilities for diagnosis and repair. With emphasis on Expeditionary Maneuver Warfare (EMW) concept, the ability to quickly diagnose and repair essential equipment as far as possible, EMSS will be able to positively identify the fault, the parts requisitioned, and the item repaired forward by contact teams. Most severely damaged assets will require to be transported to rear echelon maintenance units/facilities.

EMSS will be used as a portable maintenance aid to display technical data, display and analyze system health status, run intrusive diagnostics, assist in fault isolation and repair mentoring, and up/down load system data (health monitoring). EMSS will be fully compatible with Autonomic Logistics. EMSS will also document maintenance actions, query and order parts, maintain real-time digital equipment record jackets, and provide the ability to analyze prognostic data based on sensor input.

In order to accomplish the above-mentioned requirements the EMSS must meet the following criteria:

> iv. The EMSS must be capable of hosting Global Combat Support System – Marine Corps (GCSS-MC) software and interfacing with the logistics pipeline.
> v. EMSS will function in any clime and place. EMSS configuration are as follows: reconfigurable, portable maintenance aid, commercially ruggedized, impact and weather resistant, wearable or hand held controller with a high resolution, sunlight readable display.
> vi. Capable of storing and retrieving data files form floppy disk, CD, CDRW, DVD, flash memory cards, USB Device and

          network connections. Data collected shall be in GCSS-MC compliant format.

vii. EMSS interface must include network communication capabilities through a standard RJ45 or BNC type connector, which allow EMSS to be connected to standard protocols like TCP/IP. EMSS shall be designed to support wireless interface(s) with industry standard encryption.

viii. Must be capable of displaying and supporting user interaction with technical data manuals (IETMs), schematics, writing diagrams, parts lists, system drawings, and displaying and moving still graphic information as used in computer-based training (CBTs) and animated help files.

ix. EMSS shall support the execution of test and diagnostics routines developed in multiple programming languages and environments and will also provide a standardized style sheet for diagnostic programming of test assets within EMSS.

x. Weight must be limited to 44 pounds and must be one-person portable by 90 percent of the maintainers.

xi. Primary power – shall be capable of operating on battery power and must have a capability of recharging.

xii. Provide input devices (ie. keyboard, mouse, infrared, voice, etc.) to allow the operator to interact with the system.

xiii. Must perform a self-test capability.

xiv. Must be designed as a Open Architecture System

xv. Must be configured with a standard paper printer interface.

xvi. EMSS will not support "on board" built-in test equipment.

xvii. Be capable of emulating existing General Purpose Electronic Test Equipment (GPETE) in stand-alone and diagnostic test applications.

xviii. Standard Buss Controls – EMSS will support a wide range weapon systems and platforms.

Threat/Operational Environment:

1) The EMSS will be designed to function in both garrison and tactical environments and climatic conditions that Marines serve.

2) The EMSS is not designed to overcome threat, but rather to support a myriad of weapon systems and support equipment that are designed to overcome a wide variety of threats.

EMSS may further be transformed from a single device into a family of devices-some wearable and others handheld. The feasibility exists that "portable" display

devices, with touch screen capability; connected via wireless LAN to a central computer/network may be used.

The below-mentioned are the minimal capabilities that are required to fill the existing capability gap: 1) the ability to run computer based testing (CBT), 2) the ability to run and display technical data in the form of IETMs, 3) the ability to run onboard diagnostic through the IETM, and 4) interfacing ability to download/upload tech data from a supported system.

3.0   Operational Architecture (OA) Review

This section depicts the Operational Architecture for the "To-Be" Marine Corps logistics enterprise. The USMC Integrated Logistics Capability (ILC) team was tasked to develop a standard set of processes across the logistics enterprise, based on ILC concepts and commercial best practices. First ILC team developed the high-level OA that serves as the foundation for the follow-on efforts to develop the detailed OA for Global Combat Support System-Marine Corps (GCSS-MC). This section on Operational Architecture is organized to discuss the OA at a higher level of abstraction followed by a detailed description.

3.1   Scope and approach of OA
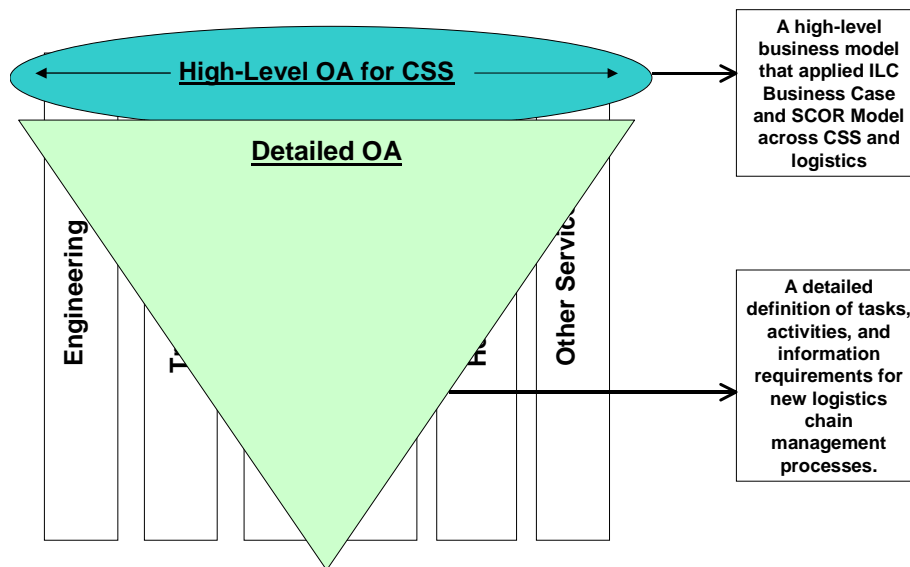
Figure 3.1: OA Scope and approach

The High-Level OA breaks down into the detailed OA where tasks, activities, and information requirements for new logistics chain management processes are defined.

The high level view of the Marine Corps' logistics chain reflects characteristics that are similar to the typical supply chain existing in commercial enterprises. For example, a typical commercial supply chain is comprised of two basic sets of activities –recognition of demand for products and services, and the fulfillment of that demand. The Marine Corps' logistics chain can be described in these terms. The consumer creates demand for products or services, and a supplier fulfills that demand. Despite the similarities between the two, the Marine Corps' logistics

chain differs from the commercial world. These differences are directly related to the organization, roles, and mission of the Marine Corps.

This fact brings up the necessity to build the context-specific detailed OA. The concepts in SCOR Model are used in describing the details of the OA. The SCOR Model breaks down business activities that are associated with satisfying consumer demand. The model outlines the steps of a logistics chain transaction, starting with the consumer inquiry through the paid invoice.

3.2   Review - High Level OA
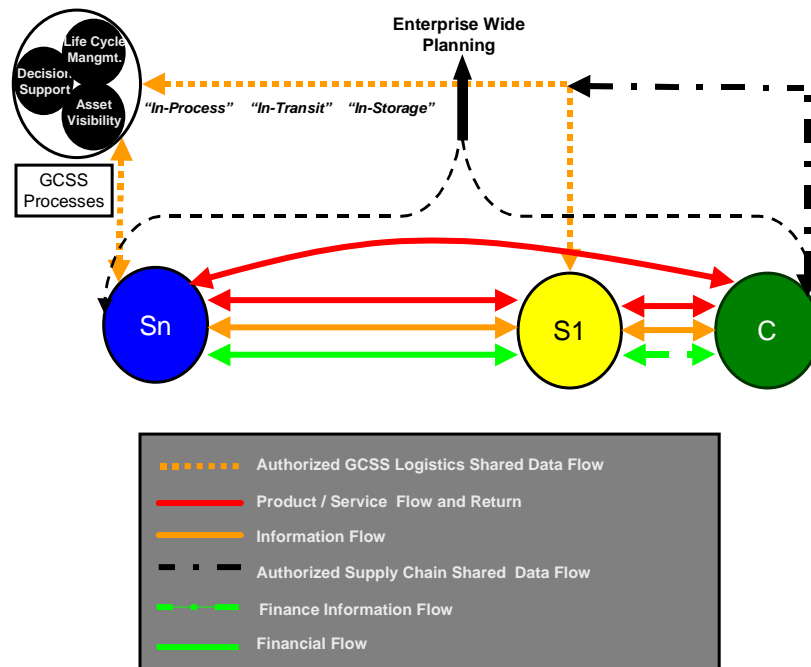
Figure 3.2: High-Level Operational Architecture

The Consumer in the "To-Be" logistics chain is defined as the ultimate consumer of products and/or services, such as a supported unit, and is depicted as "C" (Figure 3.2).

The consumer is responsible for generating demands, conducting operator level maintenance, and accounting for their resources. Demand may be reactive (e.g. unscheduled maintenance), or forecasted (e.g. scheduled re-supply), using manual (e.g. radio) and or automatic (e.g. autonomic) modes of communication. In the ILC architecture, consumer demands are passed to a single entity. This entity is depicted as Supplier 1, or the "S1" node (Figure 3.2). Supplier 1 is responsible for all logistics chain processes including order management, sourcing and the delivery of products and services for the consumer. Its primary obligation is to fulfill the demand generated by the consumer, not necessarily to

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maintain a hierarchical relationship between itself and its supplier(s). It maintains inventory and asset visibility, has intermediate maintenance capabilities, and conducts financial management for the consumer.

Consumers communicate demand for products and/or services to Supplier 1 by any available means. The orange arrow in Figure 3.2 depicts the information flow. This link is the Consumer's interface with the logistics enterprise and includes other information such as order receipt, order status, and shipping information. Demand signals from the consumer lead ultimately to the flow of products and services up and down the supply chain.

Both product and service flows are depicted by the red arrow. Supplier 1 fulfills consumer demands from organic sources and is also responsible for managing financial resources for the consumer. Financial information (e.g., available funds, account reconciliation, etc.) is passed onto the consumer. This flow is depicted by the dashed green line, which is imbedded within the information flow (orange line).

Supplier 1 is responsible for communicating with all other suppliers, vendors and service providers (called Supplier(s) N, and depicted as "Sn"). Supplier(s) N replenishes demand generated from the Consumer at the request of Supplier 1. Within the Marine Corps, Supplier(s) N activities include (but are not limited to) wholesale supply, depot-level maintenance, and management of secondary repairables. In addition, Supplier(s) N's involvement with the logistics chain enterprise is based on its relationship to Supplier1. Examples of Supplier(s) N include the Defense Logistics Agency (DLA), clinical health care provided by the Navy, transportation services provided by TRANSCOM via GTN, commercial vendors, authorized civilian agencies, or even adjacent units.

The interaction between Supplier 1 and all other suppliers gives Supplier 1 the ability to pass a demand to the next node in the logistics chain (e.g., commercial vendor or DLA).

A critical element of the logistics chain is the availability of quality data across the enterprise. This demands, "sharing" of data and is enabled by a Shared Data Environment (SDE), which is used to facilitate the flow of data throughout the enterprise.

The SDE enables members of the logistics enterprise to maintain visibility of assets that are in transit, in storage and or in processing, and provides a means of accessing information by each node in the supply chain. The SDE, which is the cornerstone of GCSS-MC, provides data that is of uniform and consistent in structure. The SDE will also provide an easily accessible repository for common data necessary to provide rapid, flexible decision support, total asset visibility, an effective planning capability (across the enterprise), and an enhanced ability to execute lifecycle management.

3.3   Review - Detailed OA
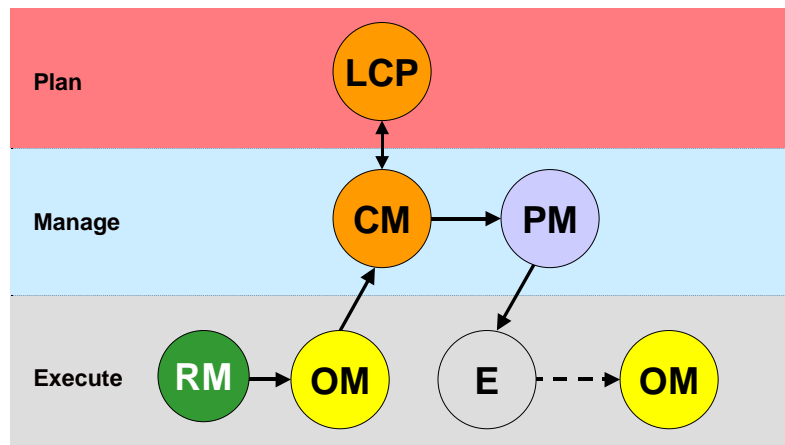
Figure 3.3: High-Level Functional Context Diagram

We will briefly explain the processes in this section. In section 3.4, we undertake a detailed explanation. Readers familiar with the OA processes can skip section 3.4.

Logistic Chain Planning (LCP) is located in the enterprise level. The duty of LCP is planning and designing logistic chain to fulfill customer's demands.

Request Management (RM) is the function for generating and approving customer demands. Basically, it works by validating customer requirements and generating requests for logistics support (fulfillment of products and services) if required. RM receives requirements from within the customer / supported unit; prioritizes requirements, sources the demand internally or processes the requirement into a request and submits the request to be created into an order.

Order Management (OM) is the function for routing, coordinating, tasking, and tracking customer orders through fulfillment. This function works by receiving requests from customers, generating customer orders (based on requests) and initiating the fulfillment of products and services. In addition, OM processes communicate order status to the customer.

Capacity Management (xCM) is the function that involves managing, optimizing, prioritizing, and planning resources and capacity to fulfill customer demands. It can be divided into 4 categories (Distribution, Inventory,

Maintenance and Procurement) each category can again be divided into other sub-categories.

Production Management (xPM) is the function for coordinating, planning, tasking and controlling how customer demands are fulfilled. It can be divided into 4 categories (Distribution, Inventory, Maintenance and Procurement) each category can then be divided into other sub-categories.

Execution (xE) is the function for executing CSS tasks to fulfill customer demands. It can be divided into 4 categories (Distribution, Inventory, Maintenance and Procurement) each category can be divided into other sub-categories.

3.4   *Operational Architecture Review: Functional Process Flows and Operational Elements*

Request Management (RM) is the function of generating and approving customer demands. Basically, it works by validating customer requirements (at an individual and aggregate level) and generating requests for logistics support (fulfillment for products and services) if required. Request Management is the customer's process of approving and generating its demands for logistics support. RM receives requirements from within the customer / supported unit; prioritizes requirements, sources the demand internally or processes the requirement into a request and submits the request to be created into an order.

The purpose of Request Management is to gather requirements at an individual or aggregate level, validate and understand the nature of the customer's requirement and to ensure that requests for products and services can be supported through capabilities in the logistics enterprise. This process also provides a means to validate requirements at the aggregate level to achieve potential economies of scale in fulfilling customer requests.

It can be divided into 4 functional flows:

- Request Management Product (RMP)
- Request Management Return (RMRL)
- Request Management Service (RMP (D))
- Request Management Service (RMP(M))

Order Management (OM) is the function of routing, coordinating, tasking, and tracking customer orders through to fulfillment. This function works by receiving requests from customers, generating customer orders (based on requests) and initiating the fulfillment of products and services. The activities in the OM process enable the Order Management function to manage customer orders from

start to completion by coordinating and decomposing requirements with and among enterprise capacities and capabilities to facilitate fulfillment of the order and to communicate order status to the customer.

The purpose of the Order Management process flow is to generate customer orders, initiate the process of product and service fulfillment, and coordinate and/or decompose all related logistics activities among the various Capacity Management activities. The Order Management process binds all related child orders to the primary order generated through the Order Management process. From the customer's perspective, the Order Management process centralizes the fulfillment process at one point within the logistics chain enterprise allowing for more efficiencies and coordinated efforts in the fulfillment process.

It can be divided into 5 functional flows:

- Order management Product (Pre & Post) (OMP)
- Order management Return (Pre and Post)(OMRL)
- Order management Service (Distribution) (Pre and Post) (OMS(D))
- Order management Service (Maintenance) (Pre and Post)(OMS(M)), and Customer Service Management (CUSTSRV-MGT)

The last one, Customer Service Management (CUSTSRV-MGT) is the process of receiving, validating, identifying, analyzing and managing the resolution of customer issues or inquiries.

Logistic Chain Planning (LCP) is located in the enterprise level. The duty of LCP is planning and designing logistic chain to fulfill customer's demands. LCP can divided into 11 subcategories as shown below

1. Logistic Chain planning - Back End (Provider Facing, LCPLAN-PRO) This flow focuses on segmenting providers into various categories and developing appropriate provider relationships with the goal of reducing the total cost of procurement and increasing collaboration. Purpose: to establish stronger relationships with providers. These strengthened relationships will lead to improvements in cycle time and elimination of waste that will result in increased effectiveness of the USMC logistics enterprise. This process also provides a common standard for comparing performance of various providers and will enable the USMC to rank and evaluate providers.

2. Logistic Chain planning - Front End (Customer Facing, LCPLAN-CUST) LCPLAN-CUST is the process of establishing customer support agreements, based on customer needs and mission priorities, to support the customer in achieving their objectives. It helps to refine the review process developed to understand customer support requirements and to provide a communication channel for customer feedback.

Purpose: to create customer support agreements that will be used to define the level of support provided to help customers meet their objectives.   The process also is used to refine the customer support review process used to communicate with customers and share requirements both from a customer and a support capabilities perspective.

3. Network Design Planning (NETDES)
   NETDES is the planning process by which the enterprise plans and manages the location, capacity and capabilities of its logistics infrastructure. The logistics network is the physical channel by which products and services are provided to the supported unit. Planning is done to configure and reconfigure the nodes and resources employed in the logistics chain network to optimize its efficiency.
   Purpose: to identify additional network capabilities required to support logistics chain goals and objectives. The logistics network must effectively meet the needs of the supported unit. Effectively managing the flow of product and services through the logistics network is critical to responding to the customer's requirements. Network design planning facilitates a cost-effective and responsive logistics network to support the customer.

4. Customer Service Planning (CUSTSVRPLAN)
   CUSTSVRPLAN is the process of capturing and analyzing data and developing a plan to identify preventative / pre-emptive measures to reduce or eliminate anticipated service failures and/or customer issues at the enterprise level.
   Purpose: to identify service remedy plans that can be used to resolve customer issues (through the customer service management process) and to recommend changes to logistics chain processes to eliminate or reduce anticipated service failures.

5. Life Cycle Management (LCM)
   Life Cycle Management emphasizes decision processes that influence system cost and usefulness efficiencies. The primary objective of life cycle management is to deliver quality systems when promised and within cost estimates using an identifiable, measurable, and repeatable process.

6. Maintenance Planning (MNTPLAN)
   MNTPLAN is the process of determining the maintenance requirements for all assets that need maintenance in an enterprise. The outcome of the Maintenance Planning process is to conduct preventative maintenance so that corrective maintenance is minimized. This approach will ensure the highest equipment availability possible throughout the equipment's life cycle.
   Propose: to plan for maintenance proactively so that all the maintenance requirements over the long term (12 to 18 months) are gathered and assessed against the available resources at the enterprise level.

7. Maintenance Allocation Planning (MNTALC)
   MNTALC is the process of allocating maintenance resources to maintenance requirements for all assets that need maintenance in an enterprise over a regular time period. Yet, it allocates a gross requirement to resources.
   Purpose: to provide an estimate of all the anticipated maintenance requirements so that appropriate stakeholders can plan the use of their assets. This plan will give stakeholders (i.e. operators of the assets) an idea about when their assets are going into the maintenance cycle. This also allows the stakeholders to plan their resources accordingly.

8. Procurement Planning (PROCPLAN)
   Procurement planning is the process of developing a strategy to replace a capability with a commercial or DoD entity, increase capacity, or provide a sourcing strategy to meet enterprise goals.
   Purpose: to produce a Procurement Plan that contains the activities required to modify the capacity of the provider and buying network to meet expected logistics chain requirements. These activities include qualification of new providers, identification of new ways to purchase, adjustment of provider contracts/agreements, identification of new products and services, etc.

9. Inventory Planning (IMPLAN)
   IMPLAN is the process of planning what inventory (by item / item category) is required, how much should be held, where it should be held (location) and when it should be reordered to support current and future demands at the enterprise level.
   Purpose: to meet anticipated demand and to determine the business rules and control parameters (e.g. order frequency, stock level thresholds, service levels, physical properties, etc.) required to effectively manage an enterprise's inventory. Ultimately, this process will help ensure that inventory is managed (i.e. positioned, monitored, replenished and controlled) according to established logistics chain objectives (i.e. balancing effectiveness/efficiencies), changing customer needs, and unexpected variances in the demand/supply environment.

10. Demand Planning (DEMPLAN)
    DEMPLAN is the process of collecting, segmenting and analyzing data related to historical planned and unplanned product and service consumption, as well as known anticipated consumption (e.g. operations and exercises) at the enterprise level.
    Purpose: to produce a demand forecast that anticipates future consumption. This forecast is based on the synthesis of customer and other segmentation criteria and enterprise constraints (budgetary,

regulatory etc.); ultimately resulting in a forecast that anticipates and fulfills the demands of the customer.

11. Return Planning (RETPLAN)
    RETPLAN is the process of collecting, segmenting and analyzing data related to historical planned and unplanned product and service returns, as well as known anticipated returns at the enterprise level.
    Purpose: of the process is to produce a return forecast that anticipates future returns based on customer and other segmentation criteria. After applying constraints (budgetary, regulatory etc.) a forecast that meets the satisfaction of the customer can be used in the inventory planning and service capacity planning processes to drive requirements.

Capacity Management (xCM) is the function that involves managing, optimizing, prioritizing, and planning resources and capacity to fulfill customer demands. It can be divided into 4 categories (Distribution, Inventory, Maintenance and Procurement) each category can be divided into other sub-categories that will be described below.

Distribution Capacity Management (DCM) is the function that involves managing and planning the distribution strategy which can be divided into 10 functional flows as list below.

1. Transportation Planning: Facility Location Capacity Planning (TRNS-FAC-LOC)
   TRNS-LOC is the process of determining the location and capacity of facilities within the distribution network. This process is primarily driven by distribution requirements identified in other planning processes. The strategy that guides this process is defined in the Network Design Plan.
   Purpose: to plan for the necessary facility infrastructure to satisfy projected distribution requirements within a particular geographic area. In this process, existing infrastructure is examined and capabilities are compared against requirements to identify excesses or deficiencies.

2. Transportation Planning: Transportation Capacity Planning (TRNS-CAP)
   TRNS-CAP is the process of determining required capacities of the links between nodes within the distribution network. These decisions are driven by distribution requirements and logistics strategies. Links can be modified, added, or removed to satisfy required capacities.
   Purpose: of this process is to provide a way of examining existing link infrastructure and comparing it against forecasted distribution requirements to identify future needs. Link capacities can be modified to enhance the flexibility of the distribution network, to plan for contingencies with alternative options, and to respond to changes in demand.

3. Transportation Planning: Facility Resource Planning (TRNS-FAC-RES)
    TRNS-FAC-RES determines the resource requirements for facilities that
    are necessary to meet distribution service demands. This process takes
    into account various factors such as throughput requirements, available
    resource options, and the available facility budget to arrive at the optimal
    resource plan.
    Purpose: to plan the resources required to realize the planned capacity.
    Resources are required at each facility to fulfill distribution services
    associated with the facility operating attributes. These resources can
    include personnel, service equipment, financial budgets, and other
    resources. The quantity of required resources at a facility is dependent on
    the distribution volumes, desired throughput and facility operating
    attributes.

4. Transportation Planning: Mode Planning (TRNS-MODE)
    TRNS-MODE determines the primary and alternate modes of
    transportation used between origin / destination pairs, series, or corridors
    in the distribution network based on forecasted demand for distribution
    services.
    Purpose: to develop a rough cut plan of which modes are most
    appropriate to carry shipments between particular locations within the
    transportation network. This plan is used to guide selection of compatible
    routes, transportation resources, and configuration of the transportation
    fleet.

5. Transportation Planning: Route Configuration Planning (TRNS-ROU-CFG)
    TRNS-ROU-CFG determines the primary routes between Origin /
    Destination pairs or a series of locations that can best satisfy link capacity
    requirements identified in Transportation Capacity Planning. This
    determination is based on various factors such as required distribution
    volumes, the range of products and services to be transported, and route
    characteristics such as available time windows and vehicle compatibility.
    Propose: to satisfy the Transportation Capacity Planning with actual
    routes. A route can be a series of roads, airways, sea-lanes, or any other
    type of path between locations. It is necessary to identify multiple routes
    for each transportation link, so that alternative options are available to
    handle changes in volume or other contingencies.

6. Transportation Planning: Fleet Configuration Planning (FLEET-MGMT)
    FLEET-MGMT determines the mix of transportation assets that best
    satisfies the distribution requirements, with consideration to the other
    aspects of distribution planning. This process also determines the pool
    points within the logistics network where the transportation fleet should be
    based to provide the highest level of service.
    Propose: to generate the optimal fleet mix (air, ground, etc.) to satisfy
    service requirements. The fleet configuration decision balances

requirements and the desired service levels against cost. This process studies what is achievable, and how to achieve these goals.

7. Transportation Planning: Transportation Allocation Planning (TRNS-OP)
   TRNS-OP is the process of allocating forecasted distribution volumes to selected routings for all distribution services over a period of time. While distribution volumes are forecasted across transportation links, there may be multiple routes that traverse each link. The distribution capacity for each link is allocated to individual routings in this planning process.
   Purpose: to refine the Transportation Capacity Plan, using the Route Configuration Plan and the Mode Optimization Plan, to determine how much capacity is required along each route.

8. Transportation Planning (Delivery Planning): Mode Optimization Planning (FLEET-MODE)
   FLEET-MODE determines the optimal and alternate modes for deliveries between origin / destination pairs, series, or corridors in the distribution network based on distribution scenarios.
   Purpose: to optimize the mix of the modes that are most appropriate to carry shipments between particular locations within the transportation network, after the fleet mix has already been determined.

9. Distribution Capacity Planning (DSTCAP)
   DSTCAP determines the required capacity within the area of operations to meet current and forecasted demand. Decisions regarding the location of capacity and the control parameters, such as throughput, link and mode capacity, and service levels that are used to manage capacity, are also resolved in this plan.
   Purpose: to plan for distribution capacity proactively and manage separate categories of capacity so that appropriate business rules are applied and a distribution capacity plan can be generated.

10. Distribution Capacity / Operations Management (DSTCAPOPS)
    DCTCAPOPS is the process of scheduling and reserving capabilities and capacity to support fulfillment requirements for distribution services. These requirements can be generated by actual customer demand, or additional demand driven by fulfillment of other services. This process also performs the management of capacity utilization to meet established performance goals and satisfy changing requirements.
    Purpose: to make decisions, (e.g., reservation of distribution capacity to a customer order, relocation of required resources), to ensure that the necessary capacity is available to meet demand. This process also serves to coordinate with other logistics capacity management functions to ensure that requirements are understood.

Inventory Capacity Management (ICM) can be divided into 2 subcategories as described below

1. Inventory Capacity / Operations Management (INVCAPOPS)
    INVCAPOPS is the process of scheduling and reserving capabilities and capacity to support overall fulfillment requirements for product demand. These requirements can be generated by actual customer demand, additional demand driven by fulfillment of other services, or replenishment requirements. This process also performs the management of capacity utilization to meet established performance goals and satisfy changing requirements.
    Purpose: to make decisions (e.g., reservation of inventory capacity to a particular customer order, relocation or rescheduling of required resources) to ensure that the necessary capacity is available to meet demand. This process also serves to coordinate with other logistics capacity management functions to ensure that requirements are understood and that the fulfillment of product needs to customers can be coordinated, measured, evaluated and managed to meet expectations.
2. Inventory Control / Demand-Supply Management (DEMSUP)
    DEMSUP is the process of analyzing and correcting variances in demand and supply due to imbalances between actual and planned consumption, and managing the adjustment of resources (inventories and/or capacities) required to correct the imbalance.
    Purpose: to account for inaccuracies in forecasted demand and inventory and capacity planning, which result in adjustments to inventory and / or resources required for actual consumption to be satisfied.

Maintenance Capacity Management (MCM) can be divided into 2 subcategories as described below

1. Maintenance Capacity Planning (MNTCAP)
    MNTCAP is the process of deciding what capacity (by type / category) is required and how much capacity is needed to support current and future demands. Decisions regarding location of capacity and the type of control parameters, such as order frequency, lead-times, service levels, etc., are determined in this plan.
    Purpose: to plan for maintenance capacity proactively. Additionally, this plan enables the enterprise to manage separate categories of capacity so appropriate business rules can be applied and a Maintenance Capacity Plan can be generated.

2. Maintenance Capacity / Operations Management (MNTCAPOPS)
    MNTCAPOPS is the process of scheduling and reserving capabilities and capacity to support overall fulfillment requirements for maintenance services.
    Purpose: of this process is to make decisions (e.g., reservation of

maintenance capacity to a particular customer order, relocation or rescheduling of required resources) to ensure that the necessary capacity is available to meet demand.

Procurement Capacity Management (PCM) can be divided into 1 subcategory as described below

1. Procurement Capacity / Operations Management (PROCAPOPS)
    PROCAPOPS is the process of scheduling and reserving capabilities and capacity to support overall sourcing requirements. These requirements can be generated by actual customer demand, additional demand driven by fulfillment of other products and services, or replenishment requirements.
    Purpose: to make decisions to ensure that the necessary procurement capacity is available to meet demand. This process also serves to coordinate with other logistics capacity management functions to ensure that requirements are understood and that the fulfillment of product needs to customers can be coordinated, measured, evaluated and managed to meet expectations.

Production Management (xPM)

Production Management is the function of coordinating, planning, tasking and controlling how customer demands are fulfilled. It can be divided into 4 categories (Distribution, Inventory, Maintenance and Procurement) each category can be divided into other sub-categories that will be described below. Distribution Production Management (DPM) is the ability to manage the distribution strategies after planning processes are determined. It can be divided into 2 subcategories of functional flows as described below.

1. Distribution Production / Operations management (DSTOPS)
    DSTOPS is the process of scheduling and reserving specific resources to support overall fulfillment requirements for distribution services. In addition, the Distribution Operations Management function will also adjust schedules and or resources according to feedback from the execution function.
    Purpose of this process is to make decisions, (e.g., reservation of specific distribution resources to a particular customer order, relocation or rescheduling of required resources), to ensure that the necessary resources are available to meet demand.
2. Transportation Planning (Delivery Planning) – Route and Schedule Planning (TRNS-ROU-SCH)
    TRNS-ROU-SCH determines the primary routes and schedules for the delivery of products and services. Running various scenario driven models and selecting the best solution determines the planned routes and schedules.

> Propose: to establish a schedule for the execution of distribution tasks or deliveries. This process covers scheduling and routing of deliveries for the logistics enterprise to meet distribution requirements generated by Inventory Planning, Maintenance Planning, and other planning processes. The schedule solution should be designed in accordance with vehicle maintenance requirements, mode capabilities, and operator limitations such as the maximum number of driving hours/day.

Inventory Production Management (IPM) is the ability to manage the inventory strategies after planning processes are determined. It can be divided into 1 subcategory of functional flows as described below.

1. Inventory Production / Operations Management (INVOPS)
   INVOPS is the process of scheduling and reserving specific resources to support overall fulfillment requirements for product demands. In addition, the Inventory Operations Management function will also adjust schedules and / or resources according to feedback from the execution function. Purpose: to make the management decisions, around inventory execution, required to ensure the necessary resources are available to meet demand for product fulfillment.

Maintenance Production Management (MPM) is the ability to manage the maintenance strategies after planning processes are determined. It can be divided into 2 subcategories of functional flows as described below.

1. Maintenance Production / Operations Scheduling (MNTSCH)
   MNTSCH is the process of scheduling maintenance resources against specific assets that need maintenance. The Maintenance Allocation Plan drives the scheduling process. The Maintenance Scheduling process commits resources to specific tasks with specific time associated with each item so that maintenance is performed at a scheduled time Purpose: to schedule equipment for maintenance at specific dates and times. This process bridges the gap between the Maintenance Allocation and the Maintenance Operations processes and can be viewed as a further decomposition of the "Schedule and Reserve Specific Resources" activity in the Maintenance Operations Management process flow.

2. Maintenance Production / Operations Management (MNTOPS)
   MNTOPS is the process of scheduling and reserving specific resources to support overall fulfillment requirements for maintenance services. In addition, the Maintenance Operations Management function will also adjust schedules and or resources according to feedback from the execution function.

Purpose: to make decisions (e.g., reservation of specific maintenance resources to a particular customer order) to ensure that the necessary resources are available to meet demand. This process coordinates with the Maintenance Capacity Management function to ensure that requirements are understood and that the fulfillment of maintenance services to customers can be measured evaluated and managed to meet customer expectations (quality order concept).

Procurement Production Management (PPM) is the ability to manage the maintenance strategies after planning processes are determined. It can be divided into 1 subcategory of functional flows as described below.

1. Procurement Production / Operations Management (PROCOPS)
   PROCOPS is the process of training and applying sufficient resources to execute procurement actions based on the anticipated volume and complexity of the requirements. In addition, the Procurement Operations Management function will also adjust schedules and or resources according to feedback from the execution function.
   Purpose: to manage the execution of procurement actions based off the procurement plan to ensure that the necessary resources are available to fulfill product and service demands. This process coordinates with the procurement capacity management function to ensure that requirements are understood.

Execution (xE) is the function of executing CSS tasks to fulfill customer demands. It can be divided into 4 categories (Distribution, Inventory, Maintenance and Procurement) each category can be divided into other sub-categories that will be described below.

Distribution Execution (DE) is the execution of distribution strategy to fulfill the customer demands which can be divided into 1 subcategory as described below.

1. Distribution Fulfillment (OFS(D))
   OFS(D) is the process of executing distribution as part of a customer order for products and services. Distribution fulfillment may entail delivering a product to a customer or include transportation of equipment. Distribution fulfillment is also the process used to move the customer and/or equipment to another location.
   Purpose: to execute distribution of product and resources to meet customer requirements for product and service fulfillment. It also related to a customer requirement for product or services,

begins with a service order linked to a customer order. The service order may have been initiated due to a product or returns order, due to a maintenance service order, or due to some other customer need requiring distribution services. The service order may also be a request for transportation services not related to product or services fulfillment, (i.e. movement of personnel, equipment or a stand alone transportation order).

Inventory Execution (IE) is the execution of inventory strategy e.g. packing, picking items to fulfill the customer demands which can be divided into 2 subcategories as described below.

1. **Warehouse Management Outbound (WMO)**
   WMO is the process of picking, packing and shipping items for fulfillment of customer orders or replenishment of inventories at other locations.
   Purpose: to execute the outflow of items from a location for fulfillment of existing and anticipated product orders either initiated through a product or service order.

2. **Warehouse Management Inbound (WMI)**
   Inbound Warehouse Management is the process of receiving items from providers (internal and external), verifying and recording assets received, recording and reporting discrepancies and storing the items for the fulfillment of anticipated customer orders. The process includes cross-docking operations for the fulfillment of existing customer orders.
   Purpose: to execute the inflow of items from internal and external providers and to ensure that the items are appropriately stored for fulfillment of existing and anticipated customer orders initiated through a product or service order.

Maintenance Execution (ME)

1. Maintenance Fulfillment (OFS(M))
   OFS(M) is the execution of inventory strategy e.g. packing, picking items to fulfill the customer demands which can be divided into 2 subcategories as described below.
   Purpose: to identify the activities necessary to fulfill any maintenance demand that has been initiated through the logistics chain enterprise. The activities identified in the flow represent the execution component of the maintenance process.

Procurement Execution (PE)

    1. Procurement Execution Fulfillment (PROCFUL)
PROCFUL is the process of fulfilling sourcing
requirements for products and services that originate
either through order fulfillment or through inventory
replenishment.
Purpose: to fulfill sourcing requests, using the most
appropriate providers and options and leveraging existing
/ new options and capacities. This process also tracks
the progress of a sourcing request(s) through to
satisfaction of the sourcing requirement.

4.0   Conceptual View of OA processes

4.1   Information flow from an end item to RM

The end-to-end logistics processes involved in generating demand, by the customer/consumer, to its subsequent fulfillment can be described only if the potential customer for the logistics chain is first identified. Requirements for products and/or services could be identified and transformed into requests in an automated fashion or could be done manually by a working personnel. As an example for the process description, we will assume that the condition based monitoring (CBM) system residing on an LAV to be the potential customer. Thus the requirements for the maintenance of the LAV will be identified autonomously and transformed into a request. The process of identifying the requirements using CBM and subsequent management of the requests are detailed in the next section.

4.2   Case study using CBM as an example
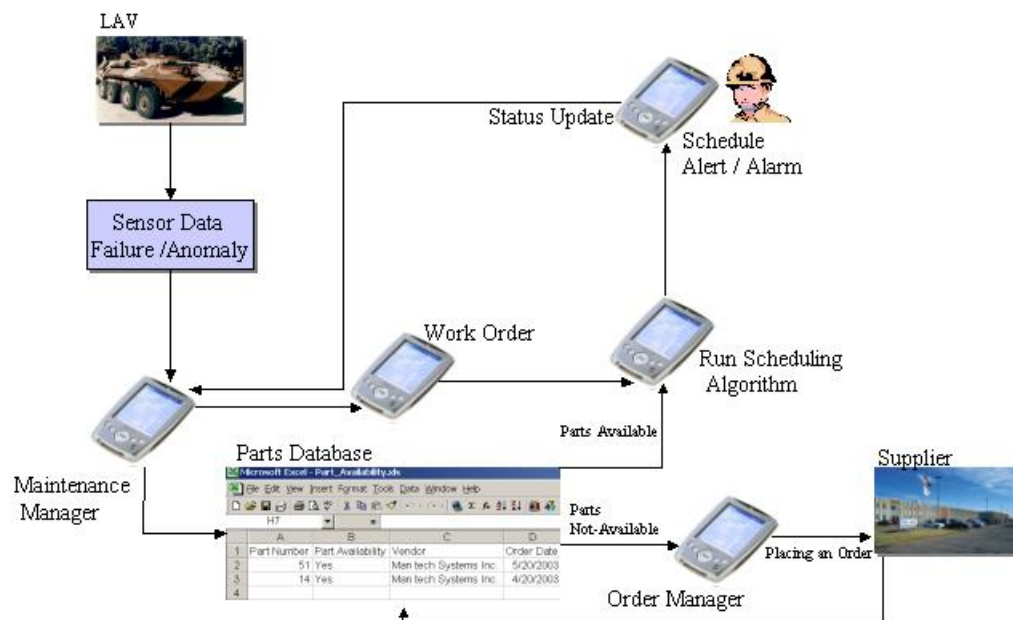
Figure 4.1: Conceptual View of Distributed Information flow

4.3   CBM Framework

The main objective of a CBM system, as the name suggests, is to monitor the health condition of the different components within the LAV. The system monitors the machinery in real time and helps assess its condition and further predicts the time to failure of these components. Thus, the judgments made by the system can be categorized as either diagnosis or prognosis. Diagnosis is defined as the judgment that is the result of the act of discovering the current nature of a fault by making a careful examination, while prognosis is the judgment about the future status based on available information and experience. An efficient CBM system would possess the powers of learning, reasoning and/or understanding to a high degree of accuracy.

Assuming that such a CBM system exists within the LAV, it would play the role of identifying a material requirement for the maintenance of a particular site. Consequently, there would be a need for the relevant equipment and the maintenance personnel so as to fulfill the maintenance requirement. The identification of these requirements by the CBM system (the customer in this example) will trigger the RM process as specified within the OA. The processing of the signal data acquired from the sensors placed on the different sites within the LAV can be processed by a unit on-board or in a centralized unit outside (server/C2). Data processing within the LAV would reduce the amount of information that would have to be transferred within the communication framework. We will assume this to be the case.

We limit the scope of this description to the RM processes and continuing analysis of the processes within the remaining functions of the logistics chain such as order management, capacity planning etc are being studied in a similar fashion but are not included within this document.

The case study uses the following data elements to describe the flow of information across the logistics chain. The list is not exhaustive but is sufficient to describe the processes entailed within RM. Note that to keep the description generic, a hypothetical component 'X' is considered for describing the request management process. The data elements used are defined below:

Site identification number – this identifies the site within the LAV which contains the component that is being monitored and further requested for as a maintenance action.

Segment identification number – This helps to narrow down the area in which the component of interest resides within the site. The scheme shows a hierarchy such that many components will share the same segment identification number and many segments might belong to a given site identified by the site identification number defined above.

Component identification number – identifies uniquely the component.

Component name – this is technical name of the component.

Component specs – this contains data about the specifications pertaining to the component.

Equipment identification number – uniquely identifies the equipment that would be used in maintenance of the LAV.

Consumer identification (machinery level) – uniquely identifies a given LAV.

LAV/Consumer operator identification – identifies the personnel within the LAV.

Service personnel identification – identifies the service personnel

Service personnel expertise – lists out the area of expertise of particular service personnel.

Supplier identification – identifies the suppliers other than supplier one (S1)

Component cost – this would be the cost of the particular component and would be part of the data shared with S1 by the secondary suppliers contained in Sn.

Request identification – This is generated each time a request is approved and submitted to the RM system.

Component life – this quantifies the time to failure (remaining life) of the component as predicted by the predictive model within the CBM system.

Work order number – identifies the work order detailing the maintenance action to be taken that is sent to the service personnel.

We will further our study of MC RM practices and substitute the names of these data elements by the corresponding MC terminology.

Figure 4.2 depicts the flow of information across the different functions of Request Management. The data elements that describe the flow of information are enclosed within the circles.
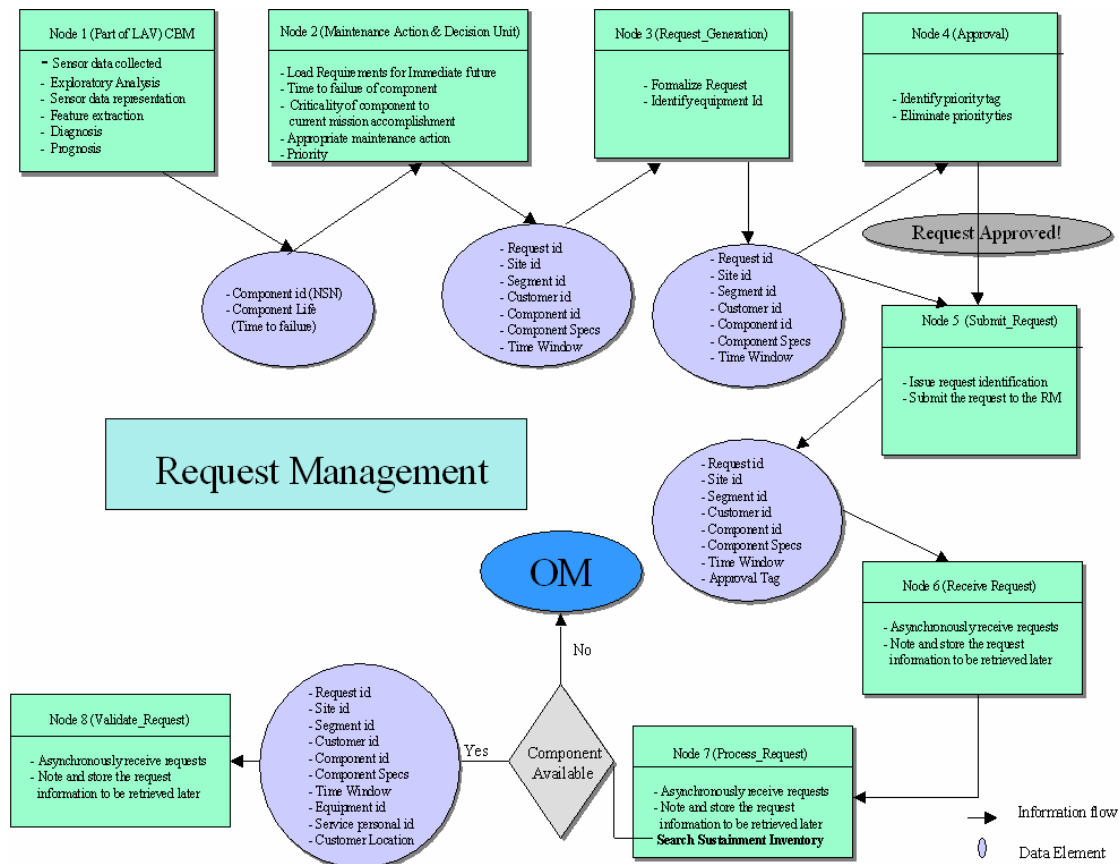
Figure 4.2: Data Elements Identified as part of Information flow for RM for CBM

4.4   Step-by-Step processes and Information flow

Identify requirement – Sensor data acquired from the various sites within the LAV are processed by attenuating the noise and by filtering out the frequency-bands that are non-sensitive to the fault of interest. The system dynamics are then captured and represented using a suitable schema. This leads to an understanding of the current status of the equipment. A suitable predictor model is used to estimate the time for failure. Thus, a requirement for the corresponding component within a given time frame is identified. Thus, at the lowest level the data type is of sensor data and the highest level has the health information and the remaining life of the corresponding component.

Information flowing through would be as follows – sensor data – extracted features – current status – remaining life. Figure 4.2 gives a detailed conceptual view of the technical processes and associated information flow.
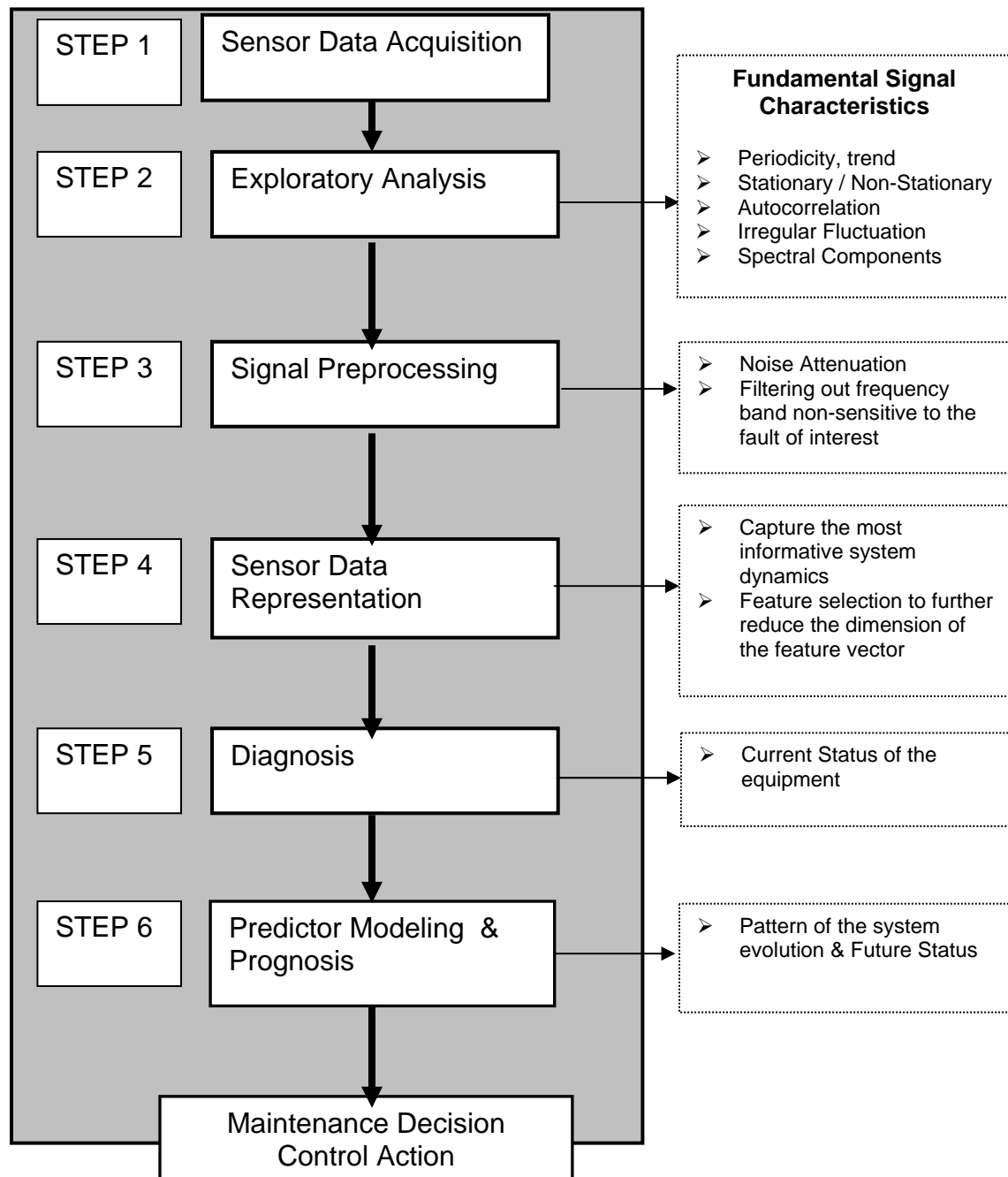
Figure 4.2: Conceptual view of the technical processes and its information flow

Validate requirement – Once the remaining life of a component is ascertained the decision for making a maintenance request has to be validated. The data is sent to the decision-making unit. This decision will be a function of the remaining life

of the part and various parameters that quantify the load requirements for the LAV in the immediate future. Note that the demands of performance from the LAV would be different when it is in garrison or when it is deployed. Thus a requirement for replacement would be validated much earlier before the predicted failure of the part when the LAV is deployed in warfare than when it is in garrison. If a decision is made for a replacement of the part or a maintenance action then relevant data including the part identification number, specifications and/or equipment requirements have to be acquired in order to generate a formal request. This data processing can be done by a processing unit within the LAV or by an information system outside. The information entailing the part ID – specs – equipment ID will be retrieved and used to generate the formal maintenance request.

Generate request - The information containing the data elements such as part ID – specs – equipment ID, customer ID location information etc have to be transformed to a suitable format that can be readily submitted to the request management system thus making it an official request for approval.

Authorize/Approve request – The designated officer/ commander is required to authorize the request for submission to the order management system.

Submit request- Once the generated request is approved then it is transmitted by wireless means to the order management system. During submission the request will be given a request identification number, using which the relevant data item within the request can be later retrieved by the supplier one (S1).

Receive request – As specified in the OA the S1 is responsible for the requests generated by the various customers. Thus the supplier 'one' (S1) who is responsible for managing the order should be ready to receive the requests that would be asynchronously generated, approved and submitted by its various customers. The information regarding the source of the requests (customer ID) has to be stored along with the different data elements within the requests so as to be able to retrieve the same while executing the fulfillment of the requirement.

Process request – The request is processed by first identifying the source for the particular part, equipment and maintenance personnel. Information regarding the availability of the part within the sustainment inventory is first ascertained. If the part is not available then potential suppliers are identified and the best fit is considered for replenishment. The data accepted and generated during processing a request would be the following – part ID, customer ID & location, sustainment inventory data and/or secondary supplier inventory data. Note that the supplier one (S1) needs to have sufficient information about the available inventory with the secondary suppliers thus calling for a shared data environment.

Validate Request- The information gathered during processing regarding the availability of the requested part with different suppliers is further validated before proceeding to generate an order. The validation might look into timeliness of delivery from the supplier so as to ensure replenishment of the part within the critical time window available in addition to considering financial data, inventory data, compliance to business rules and quality requirements for the particular part.

The validated request is then submitted as an order to the chosen supplier and the processes within order management are triggered. The information flow through the order management processes will be further studied and the relevant data types and data elements will be identified in the continuing study.

The important issues we consider are:
1) What are the best commercial practices for OA (more specifically, supply chain processes in industry) and
2) State-of-the-art wireless technologies.

Section 5 contains industry best practices for supply chain and section 6 contains a state-of-the-art report on wireless technologies.

5.0 Supply Chain: Commercial Best Practices with related websites

5.1   Grainger (LCP, xCM, xE,)

http://www.grainger.com
http://www.grainger.com/Grainger/static.jsp?page=about.html
http://invest.grainger.com/IRUploads/10160/FileUpload/branch_based_business.pdf
http://www.grainger.com/Grainger/static.jsp?page=ci_suppliers.html
http://www.darwinmag.com/read/030101/net_transformers_content.html
http://invest.grainger.com/InvestorRelations/PubCorporateOverview.aspx?partner=Mzg0TVRBeE5qQT1QJFkEQUALSTO&product=MzgwU1ZJPVAkWQEQUALSTOEQUALSTO
http://www.globalsources.com/PEC/PROFILES/GRAINGER.HTM
http://www.manufacturing.net/scm/index.asp?layout=article&articleid=CA184359
http://www.darwinmag.com/read/030101/net_transformers_content.html

Grainger established the integrated network with more than 1,200 suppliers to fulfill customer's order. Moreover, with supplier relationship management, data and information are transfer throughout the network, which can helps Grainger and suppliers manage their inventories. Grainger also offer customers the ability to order facilities maintenance products and repair parts online. Orders are placed over the Internet and transfer to one of Grainger's distribution centers for shipping or to branches for customer pick-up.

5.2   FedEx (LCP, xCM, xE)

http://www.fedex.com
http://www.fedex.com/us/about/technology/?link=4
http://users.snip.net/~gbooker/ISYS205/readings/3-Building_e-Business_at_FedEx.doc
http://www.fedex.com/us/supplychain/industrysolutions/apparel/ApparelTMS.pdf?link=4
http://www.fedex.com/us/supplychain/industrysolutions/apparel/ApparelFS.pdf?link=4
http://www.fedex.com/us/supplychain/industrysolutions/apparel/Apparelreturn.pdf?link=4
http://www.fedex.com/us/customersupport/supplychain/faq/tms.html
http://www.fedex.com/us/supplychain/industrysolutions/industrial/industrialtms.pdf

FedEx launched its Website, www.fedex.com that allowed customers to track packages online and to conduct business via the Internet. With the real-time data transmission that assists in routing and tracking packages. Information recorded by portable bar-code scanners is transmitted to a central database and can be made available to all employees and customers.

5.3   Dell (OM, LCP, xCM)

http://www.dell.com/
http://www.dell.com/us/en/gen/casestudies/casestudy_dell_i2.htm
http://www.dell.com/downloads/global/casestudies/dell_i2_NT_global_deploymen t.pdf
http://www.dell.com/downloads/us/pedge/i2%20CS%20lo.pdf
http://www.intel.com/ebusiness/pdf/affiliates/i2-dell.pdf
http://www.totalsupplychain.com/Content/MAGAZINEARTICLE/SCTN/20480/103 000.pdf
http://www.cc.jyu.fi/~hemi/filet/dell.pdf
http://www.dell.com/us/en/hea/topics/openmanage_om_main_main.htm
http://www.dell.com/html/us/segments/pub/premier/tutorial/order_status.html
http://ftp.us.dell.com/app/ps-i2.pdf

Dell applies the efficiencies of the Internet to its entire business. Customers can order the products by the website http://www.dell.com/ Dell also established the real time tracking system, so customers can see where their goods are situated during the travel of the products from the factory. Dell assembly the product based on the order from the customer. Since the order has been placed, all the materials are shipped from Dell's suppliers to the assembly factory. The make-to-order strategy reduces the inventory cost and also satisfies customer needs.

5.4   Penske Logistics (LCP, xCM, xPM, xE)

http://www.penske.com/
http://www.pensketruckleasing.com/
http://3plogistics.net/Site%20Visits/penske_site_visit.htm
http://3plogistics.net/Site%20Visits/Penske_LTEQ.htm
http://www.underdogconsulting.com/what_is_six_sigma.htm
http://www.isixsigma.com/
http://www.qualcomm.com/press/pr/releases1998/press937.html

Penske Logistics provides integrated logistics services to customers throughout the United States, Mexico and Canada. The wireless technology is used throughout the logistic system. For example, Penske uses satellite mobile communications systems to provide customer the visibility to track their products. Moreover, Penske also follows the Six Sigma Methodology (http://www.isixsigma.com/) to improve their operation performance.

5.5 *Nabisco (LCP, OM, xE, xCM)*

http://www.cpfr.org/cpfr_pdf/08_4_1_Nabisco_And_Wegman_Pilot.pdf
http://www.cpfr.org/
http://www.businessweek.com/2000/00_47/b3708071.htm
http://www.microsoft.com/resources/casestudies/CaseStudy.asp?CaseStudyID=11522

Nabisco follows CPFR strategy to share information with their distributor: Wegman. Nabisco and Wegmans exchange sales forecasts via the Web and agree on an amount to supply Wegmans. Calculations are largely based on current sales data from the checkout counter, past patterns, and upcoming promotions. The profit of using CPFR leads both companies reduce their inventory and shipping costs.

5.6 *SCOR Model 5.0 (LCP, xCM, OM, xE)*

http://www.supply-chain.org/
http://www.supply-chain.org/slides/SCOR5.0OverviewBooklet.pdf
http://www.tai.hut.fi/ecomlog/texts/SCOR_notes.pdf
http://www.sap.info/index.php4?ACTION=noframe&url=http://www.sap.info/public/en/print.php4/article/comvArticle-193333c63b63c8acf8/en
http://www.intel.com/eBusiness/pdf/it/pp023103.pdf
http://www.findarticles.com/cf_0/m1121/2_248/53638603/p1/article.jhtml?term=

The Supply Chain Operations Reference- model (SCOR) is a cross-functional framework that intent to integrate business process reengineering and process measurement. The main objective of the SCOR-model is to provide a language for communication among supply chain partners. This is done by establishing common metrics and process descriptions.

5.7 *Sapient (xCM, xPM)*

http://www.sapient.com/
http://www.sapient.com/case/usmc.htm

Sapient is the consultant company that helps a business enterprise managing their logistics and supply chains e.g. establish new enterprise workflows or architectures, customer relationship management etc. Their customers are also includes USMC logistics.

5.8   Commercial supply chain software vendors: i2 (LCP)

http://www.i2.com
http://www.dell.com/us/en/slg/topics/power_ps4q01-foreman.htm
http://www.crmbuyer.com/perl/story/20116.html
http://www.i2.com/assets/pdf/D8610BF3-D7F1-432D-B9AA6EFBC8727186.pdf
http://www.i2.com/assets/pdf/3A53A0D0-BA98-4F80-B0F76E4F0123F6B3.pdf
http://www.i2.com/assets/pdf/CSS_SEM_SRM_toshiba_css7138_0603.pdf
http://www.i2.com/assets/pdf/CSS_AER_SPM_sw_airlines_css7141_0603.pdf

i2 is the supply chain management software that helps the company mange their supply chain. i2 was created based on technologies and standards such as Extensible Markup
Language (XML), Common Object Request Broker Architecture
(CORBA ®), and Java ™. These solutions run on industry-leading application servers to provide scalability, reliability, and value to i2 ® users

5.9   Manugistics (LCP)

http://www.manugistics.com
http://www.redherring.com/investor/2000/1024/inv-manu102400.html
http://www.crmbuyer.com/perl/story/19944.html

Manugistics is the company that provides software to help customers solving their problems in supply chain management, service and parts management, pricing and revenue optimization, and supplier relationship management. Moreover, Manugistics also provides infrastructure products, strategic consulting, and implementation services.

6.0   Wireless Preliminaries and State-of-the-Art

6.1   Wireless Technology, General Comments

Making decisions on which wireless technology to use is somewhat like purchasing a computer today – in about two years, the computer that you buy today will depreciate by about 75% and will be considered "outdated" technology. As a computer owner, you realize that you have three options when making a decision to upgrade to the latest and greatest computer technology: (a) Buy a new computer and give away the old one; (b) Upgrade your current computer with specific upgrades (memory, CDRW, etc.); or (c) Do nothing and postpone your decision. We believe that making a decision regarding the purchase of wireless hardware/software (for example, a handheld cell phone) and the choice of a commercial service provider (for example, signing a contract agreement for airtime cost), follow along the same lines as what you face as a computer owner.

Given that wireless technologies continue to evolve at a rapid pace, making decisions about which wireless product or service to use is not easy. Today there are countless companies, both large and small, that deal with wireless products in some way. Assuming no catastrophic issues, such as known health effects due to wireless RF emissions, the number of companies and applications that deal with "wireless" will continue to grow into the unforeseen future.

Wireless technology is booming due to several reasons. One reason is that wireless devices are continually being developed at a very rapid pace and these devices are moving information (voice, data and video) faster and faster than their predecessors at an equal or lesser cost. Typically, a new component or upgrade to existing technology is released every nine months. The next generation devices are marketed as being able to do more, which is true, but it should also be noted that these next generation devices are smaller, consume less power, and have become reliable enough for many new and innovative applications.

It is important to mention that the next generation wireless devices will likely be based on a remarkable manufacturing technology, Micro-Electro-Mechanical Systems (MEMS), which is now beginning to take off [8]. MEMS manufacturing technology will likely revolutionize or impact most everyone's life on Earth in some way.

6.2   MEMS (Micro-Electro-Mechanical Systems)

MEMS is the integration of mechanical elements, sensors, actuators, and electronics on a common silicon substrate through microfabrication technology. The result is that a MEMS device will contain an entire "system-on-a-chip." In other words, MEMS is an enabling technology allowing the development of smart products, including wireless devices that will likely have direct application to U.S. military needs. What makes MEMS devices so attractive, besides low cost, is that each "widget" that is manufactured is a near perfect clone of the previous widget.   This means that the probability of part-to-part variability in the manufacturing process of MEMS devices is extremely low.

MEMS in wireless communications can be utilized in the area of high frequency RF circuits, especially those circuits that are inductors and tunable capacitors. Because MEMS will also play a significant role in next generation biomedical and navigational sensor systems, combining the MEMS communication benefits will be a natural fit. For example, if heart rate and location of a soldier needed to be monitored remotely a MEMs device could be used. A known shortfall with MEMS today is its ability to operate reliably in a harsh environment. For example, a MEMS device needs to be able to withstand intense vibration when mounted on a hummer vehicle that is traveling over very rough terrain. Once the reliability problems that involve the environment are adequately solved, the MEMS market will likely boom.

This report will now describe some systems engineering aspects and lessons learned when dealing with the idea of integrating wireless devices into one's everyday business practice – especially if your business is making tomorrow's decisions for the USMC. Afterwards, we will focus on technical issues we feel are important and that will need to be solved by the USMC when planning to implement a wireless device into their everyday business practice.

6.3   Systems Design Process

Though not inclusive, the USMC will need to use engineers to problem solve the implementation of a wireless device using specialized scientific and mathematical knowledge in parallel with the program manager's business plan.

In solving any complex problem, it is helpful to fully understand the interaction between analysis and synthesis [10].

Definition: Analysis is a separating or breaking up of any whole into its parts, especially with an examination of these parts to find out their nature, proportion, function and interrelationship.

Definition: **Synthesis** is the putting together of parts or elements so as to form a whole.

The following outline depicts a typical best business practice step-by-step systems engineering outline by the Pennsylvania Transportation Institute's (PTI), Center for Navigation, Communication and Information Systems (CNCIS). Following the business practice outline, we will provide more insight for systems design issues that may be faced when implementing wireless technology in the USMC. We will refine and flesh out systems design pieces as we move forward with the project and have a better understanding of USCG wireless needs. It is hoped that Phase 2 of this wireless study will allow us to complete the entire design process (as listed below) so that we may design and build a prototype USMC wireless system, directly resulting from Phase 1 of this USMC project.

1. **Needs Analysis**
   a. Question the Customer
   b. Preview the User Interface
   c. Conduct an Input/Output Analysis
   d. Prepare the Draft User's Manual
   e. Prepare the Statement of the Problem Document

2. **The Requirements Specifications**
   a. Engineer the Tolerances
   b. Specify the Prototype Testing
   c. Specify the Deliverables and Resolve Disputes
   d. Finalize the Requirements Specifications

3. **The Systems Design**
   a. Provide enough Background
   b. Organized Jobs that Need to Be Done
       i. Develop the Concepts
      ii. Model with system block-diagrams; build and model some concepts with computer simulations
     iii. Prioritize (Rank) the Concepts
      iv. Synthesize the Concepts
       v. Analyze the System
      vi. Refine, Revise and Re-Analyze the System
     vii. Finalize and Document the System Design (System Specification is now complete)

4. **Detailed Design (Combines with a separate Project Management Plan)**
   a. Implement the Prototype(s)
   b. Debug and Verify
   c. Documentation and Configuration Control
   d. Design Reviews

      e. Acceptance Testing

5. Systems Integration and Testing
      a. Complete Systems Integration of Pieces
      b. Systems Test
      c. Verify and Validate

6.4   Lessons-Learned Issues Pertaining to Wireless Integration

To add value to this project, we feel it is very important to establish some lessons-learned issues from many years of systems engineering experience in navigation, wireless communication and information systems. By all means, the list of issues below is not absolute! Each specific USMC user need dealing with wireless technology may have a unique set of technical issues or problems to solve. It should be noted that many (if not all) of the items mentioned below will likely be a candidate issue that may need engineering time to solve for reliable worldwide usage of the specific wireless system. Importantly, the answers or systems solutions to each of the issues below may likely decide the family or specific type of wireless technology that can be reliably used to meet the specific user needs.

- Use of Wireless Device Indoors/Outdoors/Both
- Power Consumption
- Power Source Issues
- Security of Data
- Intentional/Unintentional Interference or Jamming
- RF Energy/Radio Activity/ Cell Disruption/Cancer
- Electrical Noise
- Electromagnetic Susceptibility
- Electromagnetic Conductivity
- Electromagnetic Radiation
- Antenna Beam Pattern
- Antenna Gain/Directivity/ Link Budget
- Other Antenna Issues
- Reliability
- Maintainability, MTTF, MTBF, etc.
- Availability
- Timing/Delays of Information
- Frequency Availability
- Emitter Location/Detection
- Size/Weight/Packaging
- Drive-away Cost
- Upgradeability
- Ease of Upgrades
- System Software to Be Used
- Open or Closed Architecture
- Cost of Airtime or Packet Data Bits
- User Inputs
- Input/Output of Device
- Human Factors
- Use of Standards
- All Weather/All Terrain
- Limited Use in Geographic Regions
- Line of Sight
- Bandwidth
- Antenna Size and Complexity
- Velocity of User

- Distance between Transmitter & Receiver
- Encryption/Decryption
- Encoding/Decoding
- Virus Susceptibility
- Ability to Remotely Monitor and Alter Software
- Latency of data during travel time
- Unknown cloning of device (spoofing)
- Environmental Issues (Temperature/Vibration/Salt/ Water/Sand/etc.)
- Frequency of Wireless Device Connection
- Quantity of Data Being Sent
- Theft of the Wireless System
- Type of Information/Data Being Sent/Received
- Frequency of Transmission of Data/Information
- Systems Memory Limitations
- Timetable to start using system
- Cost Constraints of Drive-away System
- Voice/Text/Video Capabilities
- Remoteness of System
- Degree of Reliability of System
- Amount and Type of Building Materials/Free Space/Other that RF Energy Must Pass Through
- Other RF Energy Safety Issues (transmitting near flammable gases, etc.)

6.5   Wireless Survey

The final part of this report will provide a brief survey or overview of technologies available today, in the near future (less than five years) and in the distant future (greater than five years).   There are many commercial companies that have products available in most of the cellular and short-range wireless networks [4]. However, due in large part to high cost and risk, there are a limited number of satellite-based wireless providers. If at any time the sponsor would want more information on a given wireless technology, or fundamental communication theory (AM, FM, Duplexing, Analog vs. Digital, Digital Signal Processing, Analog to Digital Conversion, Time Division Multiplexing, Digital Modulation Techniques, etc.), we will gladly provide the opportunity to a deliver a detailed briefing.
Cellular Generations

1G: First generation phones. Analog signal. Requires higher power to maintain signal strength, shorter battery lives, no privacy protection so eavesdropping is paramount along with stealing of information (credit cards numbers, knowing what your neighbors say about you, etc.). Still popular and used in the U.S. System Technology: Advanced Mobile Phone System (AMPS)

2G: Converts analog signal into digital coded signal. Can be encrypted. Voice mail and caller ID available by means of Centrex-service decoding. Uses less power than 1G. Data rate less than 10 kbps. System Technology: Global System for Mobile Communications (GSM)

2.5G: Upgrade of 2G for higher data speed. Compresses micro-version of internet text on small display. System Technology: Wireless Application Protocol (WAP)

3G: Faster data transfer rates. Telephones that will use this technology will essentially be PC-type powerful microcontrollers. This technology will interface with both Wireless Area Network (WAN) and Local Area Network (LAN). Transfer rates to 2 Mbps in ideal conditions.

4G: Are being developed now on a limited basis. Are being planned to provide near real-time virtual reality by year 2015. Data rates to 100 Mbps.

6.6   Cellular Networks

Nearly all mobile commercial systems in use today are cellular. In other words, the user's mobile cellular device relies on communicating with a ground-based tower (cell-tower).   The ground-based towers are strategically located to provide coverage that will "see" the mobile user's cellular signal. A cell is defined as the coverage area of a single base station. Microcells are small cells that cover a very small area such as a city block or particular building. Microcells are used where

there is a high density of users, or are used to help assure overlap coverage or extra reliability for the cellular network. A handoff or handover is the process where one cell-tower switches the mobile user from one cell to another cell-tower and cell. Duplexing is the term used to represent two-way data flow.

There are two common duplex methods: frequency division duplex (FDD) which requires two separate frequencies for transmitting and receiving, and time division duplex (TDD) which quickly alternates between transmitting and receiving on a single channel. Multiplexing allows many mobile users to share the same spectrum without RF interference with a neighboring mobile user. There are several family types of multiplexing techniques: frequency division multiple access (FDMA), space division multiple access (SDMA), time division multiple access (TDMA) and code division multiple access (CDMA).

FDMA: This system gives each communication channel its own specific frequency. System Technology: AMPS.

SDMA: This system is often used when narrow-focused RF signals are required instead of omnidirectional broadcast signals. For example, it is used for special cases on the ground or for space-based networks.

TDMA: This system allows a single communications channel to be used simultaneously by multiple users. Because this is a time-dependent system, it maintains reliable coverage by limiting the cell tower radius to be no more than 30 kilometers. This radius is determined by the inherent time delays that occur in the time it takes for the mobile user's RF signal to travel through space and be received by the cell tower. Personal Communication Services (PCS) Standards: High Speed Circuit Switched Data (HSCSD) and General Packet Data Radio Service (GPRS). System Technology: GSM.

CDMA: This system is a spread spectrum technology that inherently is very difficult to eavesdrop or spoof. Two common types of spread spectrum (SS) are Frequency Hopping (FHSS) and Direct Sequence (DSSS). All CDMA technology uses DSSS. In CDMA, all users can simultaneously broadcast. The well-known Global Positioning System (GPS) signals also use spread spectrum technology.

OFDM: Orthogonal Frequency Division Multiplexing (OFDM) is used to help solve multipath effects that occur when strong reflected signals are received and interfere with the true signal. The reflections often occur because of nearby building structures or other obstacles. Special technology is available if multipath is a serious issue.

6.7   Personal Communication Services (PCS)

PCS today is made up of cellular or private mobile wireless technologies that were intended to send voice or text information. Table 6.1 below is hoped to give the reader an idea of the technology name and maximum theoretical data rates. Technical details have been omitted for each technology listed in Table 6.1, but can be researched further for this project, if needed.

Table 6.1: Common Personal Communication Services

Technology	Maximum Data Rate (kbps)	Voice? (Y or N)	Comments
MOBITEX	4.8	N	Developed by Ericsson; used for telemetry applications
D-AMPS (*Digital Advanced Mobile Phone System*, also known as ADC, NADC and USDC)	9.6	Y	Used in U.S.; compatible with Analog AMPS technology
GSM (*Global System for Mobile Communications*)	14.4	Y	Uses multiple frequency allocations; early standard in Europe
PDC (*Personal Digital Cellular* or *Japanese Digital Cellular*)	14.4	Y	Used in Japan; based on D-AMPS; compatible with Japanese analog (J-TACS).
CDPD (*Cellular Digital Packet Data*)	19.2	N	Packet-switched packet data system to AMPS and D-AMPS
TETRA (PRIVATE MOBILE RADIO) (*Trans-European Trunked Radio*)	28.8	N	Designed by ETSI; good security; used a lot in emergency services; low frequency technology (400MHz)
HSCSD (*High Speed Circuit Switched Data*)	57.6	Y	Upgrade to GSM
CDMAONE (aka IS-95a)	64	Y	Developed by Qualcomm; uses CDMA; Standardized by the Telecommunication Industry Association
IDEN (PRIVATE MOBILE RADIO) (*Integrated Digital Enhanced Network*)	64	N	Developed by Motorola; operated by Nextel
GPRS (*General Packet Radio Services*)	115.2	Y	Works with GSM
MCDN (*Microcellular Data Network*, aka Ricochet)	128	N	Metricom developed; designed for internet access; needs tiny cells <500m spacing

6.8   Mobile Data Services

Digital cell phones generally use three types of mobile messaging services. Each service and its message length are listed in Table 6.2 below. Typically, one byte of digital data corresponds to an alphanumeric character.

Table 6.2:   Common Mobile Data Services

MDS Service	Technology	Message Length (maximum, in bytes)	Message Direction	Comments
SMS (*Short Message Service*)	ALL PCS DIGITAL	160	One way and Two-way	Originally developed for GSM; messages must be short
USSD (*Unstructured Supplementary Services Data*)	GSM	182	Two-way, only	Connection must be placed with receiver phone
CBS (*Cell Broadcast Service*)	GSM	1395	One-way	Concatenates up to 15 pages, each of 93 bytes

6.9   Third Generation Technology (3G)

The international mobile telecommunications (IMT) put forth a standard called IMT-2000 to help develop the future of mobile telecommunications systems. IMT-2000 is essentially a plan for cellular networks to provide high-speed data. Such service applications available in IMT-2000 would be applications such as web surfing, email, telephony, television and video teleconferencing, using both circuit-switched and packet types of data transmission.   Some of the enabling technologies that will likely be seen in the next five to ten years are listed in Table 6.3 below. Data rate claims for 3G technologies range from 256 kbps to 2 Mbps.

Table 6.3: 3G Technologies

3G Technology	Comments
W-CDMA (*Wideband CDMA*)	Bandwidth of 5 MHz (25 times that of GSM); backward compatible with GSM
TD-CDMA (*Time Division W-CDMA*)	Time division duplexing is used to share a single channel with uplink/downlink
UMTS (*Universal Mobile Telecommunications System*)	European W-CDMA
CDMA2000	Upgrade to the existing CDMAONE
EDGE (*Enhanced Data Rates for GSM Evolution*)	Based on TDMA; migration upgrade from D-AMPS
Enhanced GPRS	Similar to EDGE, but is to be backward compatible with GSM, HSCSD and GPRS

6.10   License-Free Short Range Wireless

The International Telecommunications Union (ITU) has designated several frequency bands for industrial, scientific and medical purposes that can be used without applying for a license. In other words, it can be considered license-free wireless radio. Wireless LAN (802.11), cordless telephony, small-localized pico-cells infrared (IrDA) and BLUETOOTH make up the technologies available for short-range mobile users. Future short range devices are being developed using MEMS technologies, allowing a plethora of additional low-cost wireless applications.

6.11   Space-Based Mobile Wireless

Cellular coverage may not be uniform and currently does not include 100% of the available land-base coverage, worldwide. The previous statement is also true for the United States. Also, cellular coverage does not exist when the user is a relatively short distance away from coastal areas (for example, during oceanic travel). Methods do exist, however, to send and receive wireless transmissions to an end user in some remote part of the world. One method is using Space-Based Mobile Wireless technology. Unfortunately, most satellite-based systems are in financial trouble. A short list of Mobile Satellite networks is listed in Table 6.4. User equipment for low earth orbit devices are generally small, portable, more energy efficient and cost less than other satellite systems of higher orbits.

Table 6.4: Satellite Communication Systems

System	Data Rate (kbps)	Frequency (GHz)	Orbit Type	Comments
Iridium	2.4	1.6	LEO	Motorola based; was to shut down and intentionally burn space vehicles; expensive equipment
ICO	64	2.0	MEO	Planned: voice, wireless Internet and other packet-data services; acquired majority interest in GLOBALSTAR
GLOBALSTAR	9.6	2.5	LEO	Simple and relatively low-cost user equipment; user equipment can be automatically linked to the internet; uses ground stations
TELEDESIC	2000	20	LEO	Global broadband; internet in the sky
SKYBRIDGE	2000	10	LEO	Planned: link space and terrestrial in providing DSL
ORBCOMM	2.4	0.147	LEO	Provides two-way digital messaging, data communications, and geo-positioning services

6.12   Summary

This section attempts to summarize the current wireless technology being used in mobile wireless applications while minimizing the scientific or mathematical theory of each wireless system.   Importantly, this white paper also lists systems engineering topics dealing with lessons-learned from integrating wireless devices into previous mobile-type projects. We view the wireless technology described in this white paper as "tools of the trade" when systems engineering a particular solution for a commercial or military application. We also view the wireless technologies depicted in this paper as being "in constant motion"; meaning that each technology is rapidly being "one-upped" or "tweaked" in a never-ending struggle to reliably increase data rates using less bandwidth, while remaining backward compatible. Because the technology is being developed rapidly, the situation of choosing a wireless technology when the possibility that the technology is outdated in little time (one to two years) will likely occur for the USMC. The 4G or NextG systems are future systems that continue to "push the envelope" where wireless data speeds increase, these same future technologies are hoping to take a major step at seamlessly integrating or fusing information between neighboring wireless devices and other wireless embedded technologies. Some additional reading on seamless integration (the concept of using software radio) can be found in [5,6], with additional related wireless applications found in [4,7,9].

7.0   Work Continuation and Request for Material

Work Continuation:

In the next three months, we will accomplish the following tasks:

1. Select a subassembly of LAV for further analysis. A detailed analysis will give us the components and maintenance practices.
2. Analyze the OA processes in further detail to arrive at how 1 can be re-engineered to fit 2.
3. Investigate the detailed integration of the above in the overall AL conceptualization.
4. Identify the key data elements corresponding 1,2, and 3.
5. Prepare the information flows along with the key data elements.
6. Clearly, identify the data elements that need to be using wireless.
7. Clearly, articulate why the items in 6 need to be implemented in wireless.
8. Build a conceptual framework for wireless implementation.
9. Periodically review our progress with the sponsors.

Request for Material:

1. Though we have surveyed several web-based material on AL we need some detailed clarifications. It will help us if MC POCs can arrange for an in-depth-interviews on AL.
2. We do not have enough material and understanding of GCSS-MC, and we will need more detailed information.
3. We want to interview MC officers/personnel for understanding the maintenance and associated logistics processes and protocols.
4. With specific reference to LAV it will help us to go through the in-depth maintenance process of one component/sub-assembly. This will help us in coming-up with specifications for implementation.

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Interim Report 2

Enabling Logistics with Portable and Wireless Technology Study

AUTHORS

The Pennsylvania State University, University Park, PA 16802
School of Industrial Engineering
  Dr. Soundar Kumara
  Dr. N. Gautam
Pennsylvania Transportation Institute
  Dr. Zolton Rado
  Dr. Robert Gray
School of Information Sciences & Technology
  Dr. Dave Hall
  Dr. Irene Petrick
Project Manager: Col. Barney Grimes, USMC (Ret)

MCRU PROGRAM MANAGER

Lt. Col. Ron R. Madrid, USMC (Ret), Penn State University

TO SATISFY THE REQUIREMENTS OF

DATE

08 December 2003

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1.0 Executive Summary

1.1 Project Description and Focus

In recent years, significant advances have been made (and are continuing to be made) in the technology associated with wireless communications.   Advances have been made in devices such as wireless sensors, portable computing devices, and local and wide band communications systems. This study is aimed at conducting a broad-based assessment to identify, describe and quantify how portable wireless technology can be used to improve the effectiveness of logistics processes defined in the Marine Corps Logistics Operational Architecture (OA) as it interfaces with the Global Combat Support System—Marine Corps (GCSS-MC).   It is anticipated that the rapid evolution of commercial technology in portable and wireless technology can be leveraged to improve the ability of the Marine Corps for areas such as:

- Automated detection and characterization of the state of USMC platforms and systems;
- Communication of system and human needs from the local point of service (POS) to regional and global arenas;
- Establishment of new supply chain information concepts and logistic situational awareness;
- Improved logistics based on improved (more precise) knowledge of what supplies and parts are needed and when they will be needed; and
- Transformation of current logistics planning to an accurate, predictive "preparation of the logistics battle space" concept analogous to current intelligent preparation of the battlefield planning.

1.2 Objectives

The utilization of portable computing and wireless communications provides an opportunity to significantly change and improve the logistics and operational readiness of the USMC.   The ability for individual platforms and individuals to provide information about equipment needs, anticipated failure conditions, current state of each weapon and support system will allow the USMC to become "leaner" and more effective.   Using the terminology of Secretary of Defense Rumsfeld, this will provide "more teeth and smaller tail" fighting force capability for the USMC.

The objective of this project is to develop an understanding of the current state of the art and anticipated near-term advances in portable and wireless technology and to make recommendations on the utilization of this technology to improve

USMC logistics, within the context of the Marine Corps Logistics Operational Architecture and interfaces with the Global Support System-Marine Corps.

The research will be bounded and guided by the following considerations.

- Focus only on the logistics process and metrics within the operational architecture;
- Concentrate on processes that are good candidates for portable and wireless implementation based on the analysis of the sponsor;
- Evaluate the impact of portable/wireless technology on logistics processes using the performance metrics described within the OA logistics scorecard;
- Commercial-off-the-shelf (COTS) technology must interface with current and future systems architecture as described within the OA;
- Focus on critical, high priority weapons systems, services and supplies;
- Portable-wireless technology solutions will comply with or function outside the radio-frequency controls dictated by current military policy; and
- Recommended solutions should be deployable with Marine Air Ground Task Forces and interface with GCSS-MC as it is currently envisioned.

1.3   Current Focus

The first phase of our study focused on:

- Comprehending the Operational Architecture (OA)
- Understanding commercial best practices in logistics
- Survey on wireless preliminaries and state-of-the-art

These were reflected in our Interim report # 1 (dated 8th September 2003). Feedback given by Lt. Col. Lermo in his e-mail (dated 23rd October 2003) helped us refocus our efforts to analyze the problem from a strategic perspective. We have also augmented the broad-brush strategic perspective with detailed technical specifications. These activities are driven by the fundamental motivation to study the applicability of wireless technologies to the detailed OA processes. This document details the following:

- Application of RFID tagging for in-transit inventory tracking
- Use of GPS to capture the location information
- Applicability of wireless technologies to enable the specified OA processes

1.4   Operational Concept and Vision

Elements of the Combat Service Support (CSS) are Supply, Maintenance, Transportation, General Engineering, Health Services, and Other Services.   The logistics functionalities within the Operational Architecture that are significant to CSS are Request Management (RM), Order Management (OM), Procurement (PM) and Execution (E).

An event could be triggered within any of the CSS elements by a generated "Request". This will further trigger subsequent OA functions and their underlying processes that are specific to that particular element. An automated system (either autonomous or with a human-in-the-loop) can either be using a data repository and/or a shared data environment. Based on the unavailability of the services/ products, a request will initiate the "procurement" processes at the Enterprise Level. The service/product will be made available to the supported unit by complying with the "execution" processes.   Efficiency of operations within each of the CSS elements can be enhanced using currently available devices and emerging technologies.   Figure 1.1 shows the envisioned operational concept.
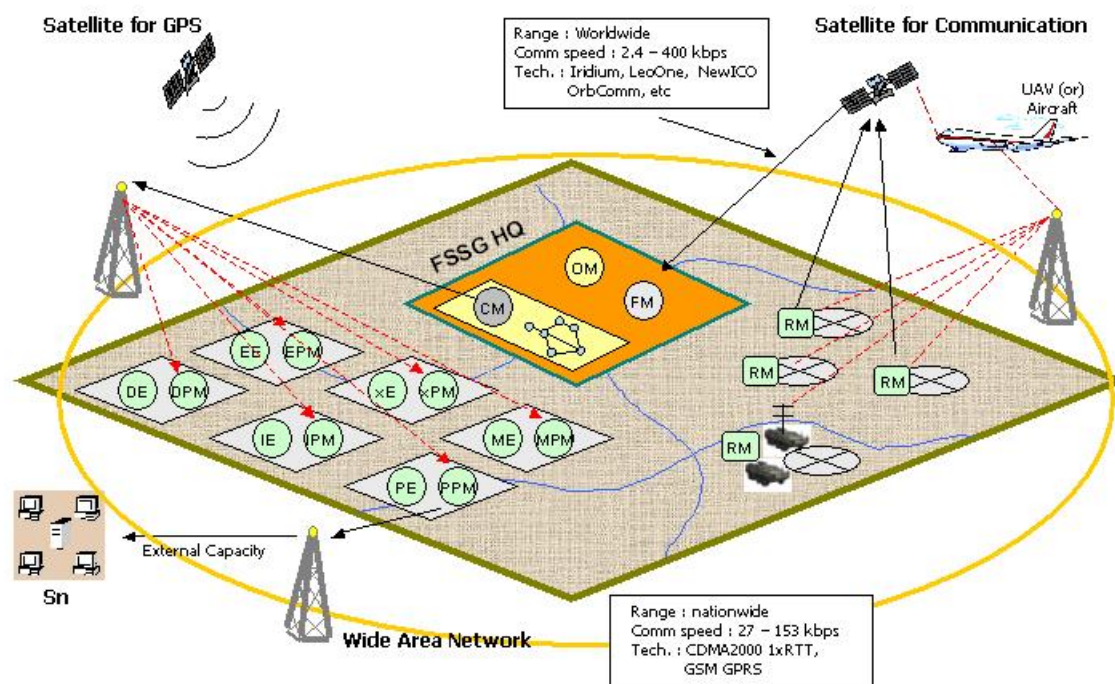
Figure 1.1: Envisioned Operational Concept

We have considered the deployment scenario represented in Figure 1.1 as our foundation for research, design and development of the wireless based infrastructure. It must be noted that this is our initial vision. This will be updated as we further our work. Though the processes involved for services and support are identical, the requirements of technologies and devices that will enable them vary drastically between the garrison and deployed environment.

We consider a Marine Expeditionary Force (MEF) that can execute concurrent sea based operations and sustained operations ashore. The supporting element (S1) would be the Force Service Support Group (FSSG). Within MEF, a self-sustainment for sixty days is available.

The MEF is assumed to contain using units with RM capabilities, FSSG, and Sea-based vessels. The supported unit generates a request using electronic forms available on the portable devices. This information is wirelessly transmitted to the supporting units. The sources for the requested services/product are identified as follows:

- For services, the availability of personnel is determined by broadcasting messages (work orders, etc.) within the concerned unit.

- For products, availability within the sustainment-supporting unit is determined by means of automated identification (such as RFID tags etc.).

After identifying the services/products they are transported to the customer. The scheduling system needs to be aware of the availability and location of the transporting units with respect to the customer. The location information of the customer and transporting units in real time is captured using Global Positioning System (GPS) enabled devices that will continually transmit the location information to a centralized server. The timeliness of transmission depends upon the bandwidth availability. The candidate transport execution unit(s) is identified and routes are generated to assist the navigation. Geographical Information Systems (GIS) in combination with the sensor systems such as "smart dust" are used to generate routes. During transit, the contents within the transporting unit are traced which facilitates the commanding officer to reroute the shipment, in the event of contingencies. GPS and GIS will aid the transporting unit to obtain real time feedback for navigation and also to deliver the products. Upon arrival at the customer, the relevant RFID tags are scanned to generate an automated receipt that is used subsequently to update the inventory database.

1.5   Methodology

Our top-down and bottom-up approach is shown in Figures 1.2 and 1.3.
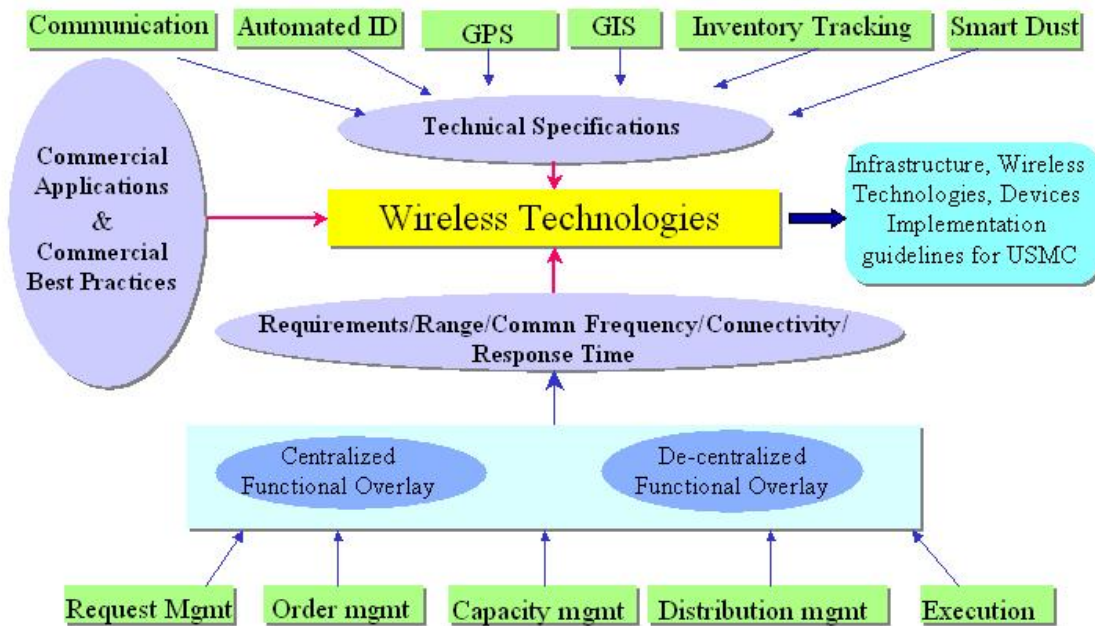
Figure 1.2: Research Methodology
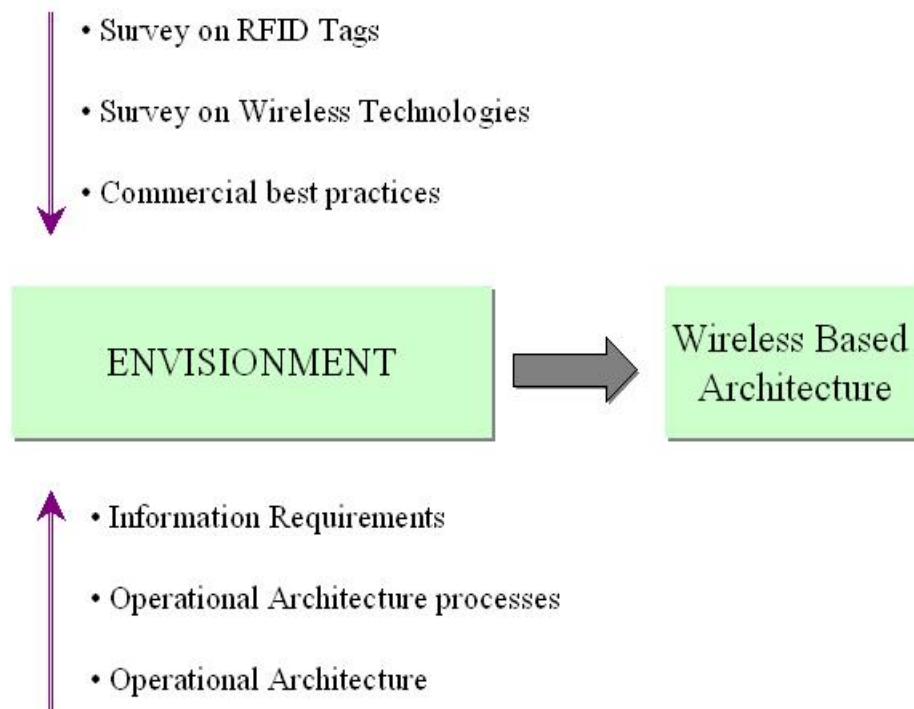
Figure1.3: Top-down and bottom-up approach

Our current focus, Section 2, is on the higher-level aspects, top-down, of commercial practices, wireless technologies and application of these technologies to USMC logistics. This gives a broader technology road map.

We also deal with the detailed aspects of the OA processes and their specific information requirements in Section 3. Following this bottom-up approach we map the information requirements to the wireless technologies identified from the top-down and build a detailed computational architecture for implementation at SCOR Level 4.

The detailed research steps are as follows:

- Literature survey on RFID tags
- Literature survey on Wireless Technologies
- Case studies of commercial wireless applications
- Understand Individual OA processes
- Identify OA process information
- Compute required bandwidth, frequencies etc.
- Construct a Wireless-OA- Infrastructure

Much of the above is covered in the Report. We have included a brief summary of each of the above in their respective chapters. Each chapter is supplemented by appendices giving detailed information. Chapter 2 deals with a broad-based survey of RFID technology followed by its commercial applications. Chapter 3 deals with a specific scenario for centralized support service and its relevant OA details. Chapter 4 discusses detailed specifications of wireless technologies.

2.0 Literature Review

In today's hi-tech world, no single day passes without reading or discussing about the emerging wireless technologies and its impact on various organizations and industries. Wireless technologies encompass Wi-Fi Networking, Personal Digital Assistant (PDA), Cell-phones, Global Positioning System (GPS), Electronic Sensors and Radio Frequency Identification (RFID). Among these technologies, RFID's along with GPS are becoming popular for real time tracking of goods, people and assets. Researchers in the area of RFID's are engaged in rigorous studies to make this technology cost-effective, usable in real time and adaptive to any organizational structure.

Implementation of RFID will have immense affect in the areas of Supply, Inventory and Warehouse management. A tag will consist of a RFID chip and an antenna. These tags help to track products within a production area, on a shop floor, supplier-customer product distribution, etc. Bar codes that are currently used to track inventory employs a line-of-sight technology to capture only the product type when passed through a scanner. However, capturing real time data through RFID tags will facilitate decision-making.

Many suppliers are focusing their interest toward RFID's that will provide them with real time status quo of their products either in the store-shelves or during distribution/transportation. Pilot programs using RFID are being conducted in various industries to analyze effect on organizational structure and performance. A survey on RFID's was performed and a detailed summary about RFID technology, its inventory tracking capability, and some interesting applications of RFID tags placed on actual items are presented in Appendix [6.1].

In continuation to Appendix [6.1], various case studies related to RFID applications in specific environments were studied and are summarized in Appendix [6.2] and [6.3]. Case studies include FedEx and UPS tracking information, wireless systems in warehouse inventory control. These case studies helped us to learn about the innovative technologies together with RFID systems that are being introduced in Boeing and UPS. Within Boeing, a start-up called Intratab has been introduced. They are electronic tags that have the same tracking capabilities as RFID systems but with additional capabilities like Time Temperature Indicators (TTI). TTI will help to improve the quality and freshness of perishable products (Appendix [6.3]). UPS along with Motorola developed Delivery Information Acquisition Device (DAID). This device is the first and only hand-held computer in the industry to both collect and transmit real-time delivery information at virtually the same time. Also, these devices can read both Barcode and Maxicode. Maxicode is a two-dimensional, machine-readable, package label code that is able to store up to 100 characters on a one-inch square. The utilization of the Maxicode enables UPS to reduce its data entry needs for shipping information to virtually zero. FedEx uses a system called Customer

Operations Service Master On-line System (COSMOS) for package tracking and also monitors every phase of delivery cycle at FedEx. Figures 6.2.8 and 6.2.9 in Appendix [6.2] show some major program applications and products that FedEx has developed to address various functions in the Entire Supply Chain and all the processes from receiving an order from a customer through to fulfillment. More details related to Automated Tracking System in UPS, Logistics and Supply chain management of FedEx, FedEx and e-commerce are summarized in Appendix [6.2].

3.0 OA Processes and Wireless Technologies

This chapter focuses on:

- Significant Operational Architecture processes like Request Management, Order Management, Capacity Management, Production Management, and Execution

- Information flow between the processes, and

- Various types of devices required for implementation

The processes are specified from an operational perspective but there is a need to determine the underlying technologies that will enable these processes. The use of a particular technology will greatly affect the efficiency and performance of the service support group. In order to determine the relevant wireless technologies and portable devices that are relevant to specific OA processes, we have to first define information and organizational overlay. Defining these will subsequently enable rigorous analysis. Once the nodes within the defined scenario are identified, use of wireless technologies as opposed to a wired infrastructure, for the different segments, can be assessed. We have identified information flows between the various OA processes. We have used the formalisms derived from software agents to analyze and tabulate information flows systematically. The use case and workflow diagrams from the OA CD are used to derive the detailed information [OA-CD]. Our aim is to arrive at requirements for the computational architecture to SCOR Level 4.

3.1 Centralized vs. Decentralized Service Support

The service support operations and the relevant information processing can be viewed as centralized or decentralized. These essentially correspond to both the functional overlay as well as the association between the service support groups and the various using units. In the centralized overlay as shown in Figure 3.1, one service support group is responsible for supporting the various deployed units. The requests are transmitted to a central Enterprise Resource Planning (ERP) system residing within the support group and orders are processed by the ERP system using the global information.
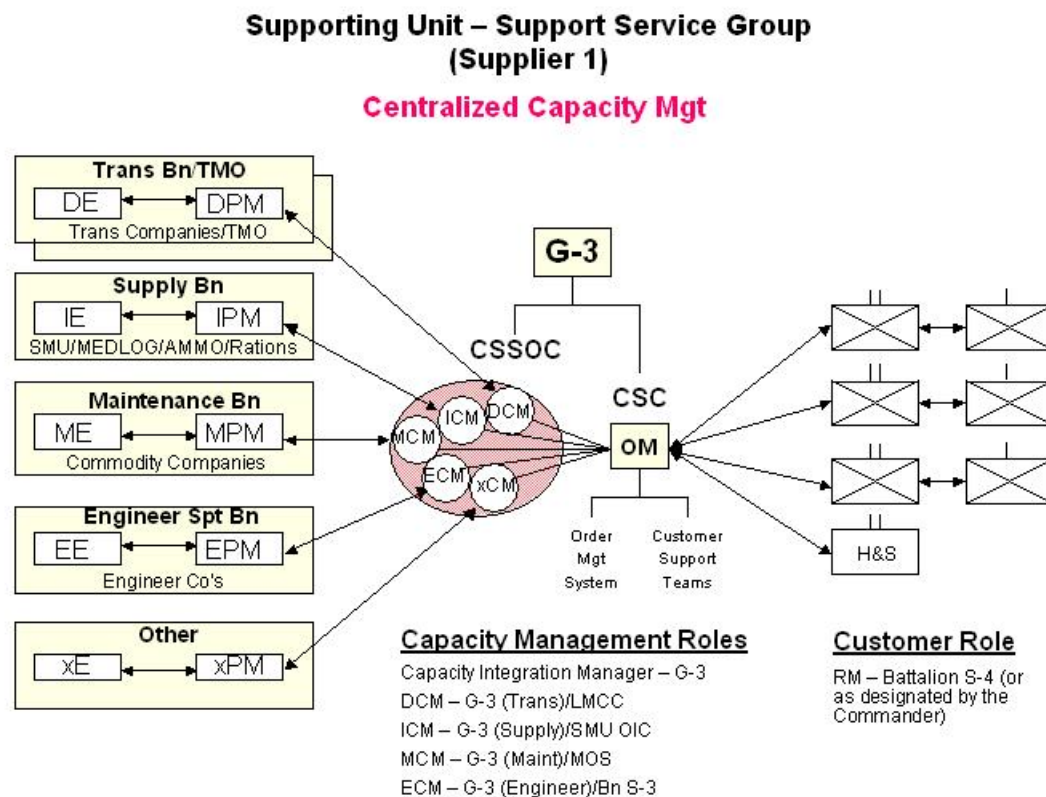
Figure 3.1: Centralized Support Service [OA-CD]

Figure 3.2 shows the decentralized layout, which considers a number of using units each of which is supported by a service support group. Requests are routed to the relevant ERP system within each of the CSS domains depending on the type of services/products requested.
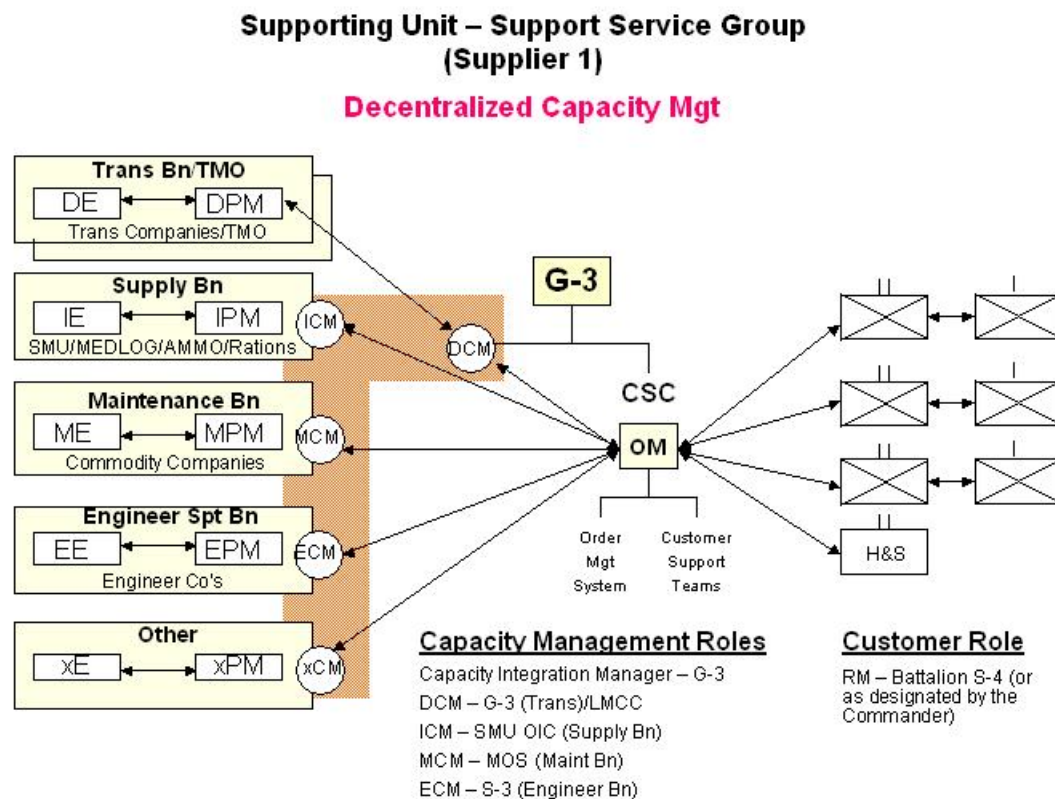
Figure 3.2: De-Centralized Support Service [OA-CD]

In both the centralized and decentralized perspectives, communication and content play a critical role in determining the efficiency of operations. In addition, we also need to consider the algorithms and technologies that will be necessary to assist the operations related to production and execution units.

3.2   *Centralized Operations*

In this section, we focus on the centralized layout. This study will later be extended to the de-centralized view as well. Figure 3.3 shows an aerial view of a centralized support service group with its associated communications and satellites.
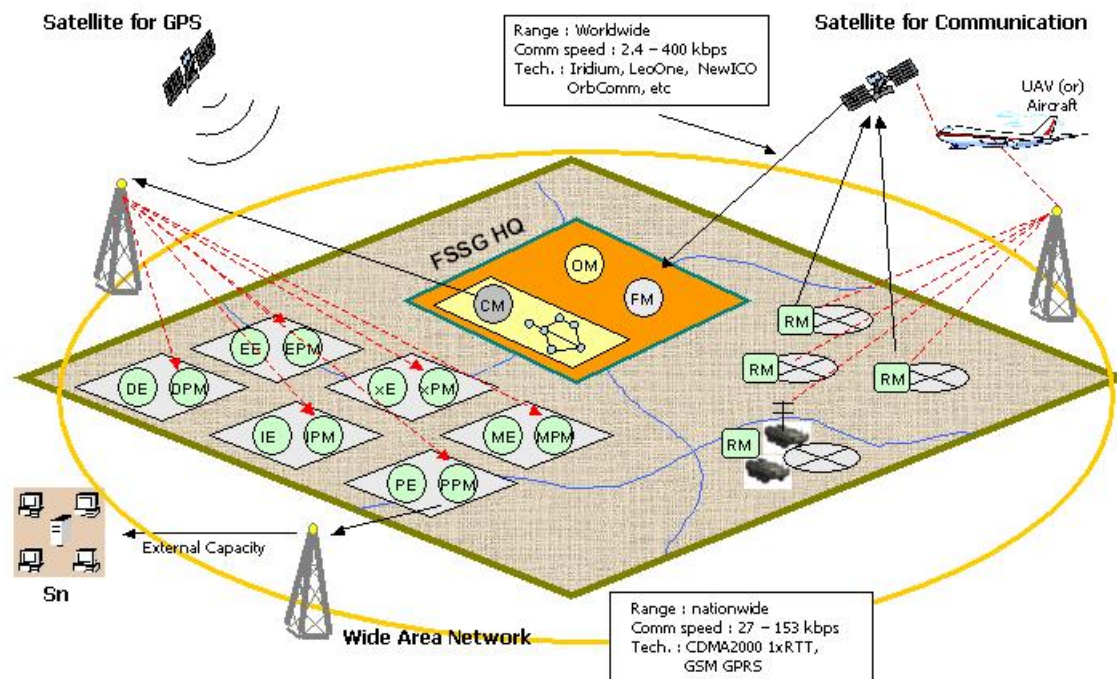
Figure 3.3: Aerial view of a Centralized support service group

The using units are dispersed geographically and are connected in real time to the service support group to obtain the relevant products/services for mission accomplishment as well as sustainment while constantly maintaining mobility. The requests made by the using unit are routed to the relevant personnel/system in the support group via satellite communications who have access to the capacity, production and execution data for the entire cluster of using units. Data is then transmitted either by means of satellites or base stations within the deployed area. The location information is captured through GPS satellite. To meet the inventory threshold for various products/services, procurement orders are transmitted to the suppliers (Sn) through Wide Area Network (WAN).

3.3   Information Flow for a Centralized Service Support Group
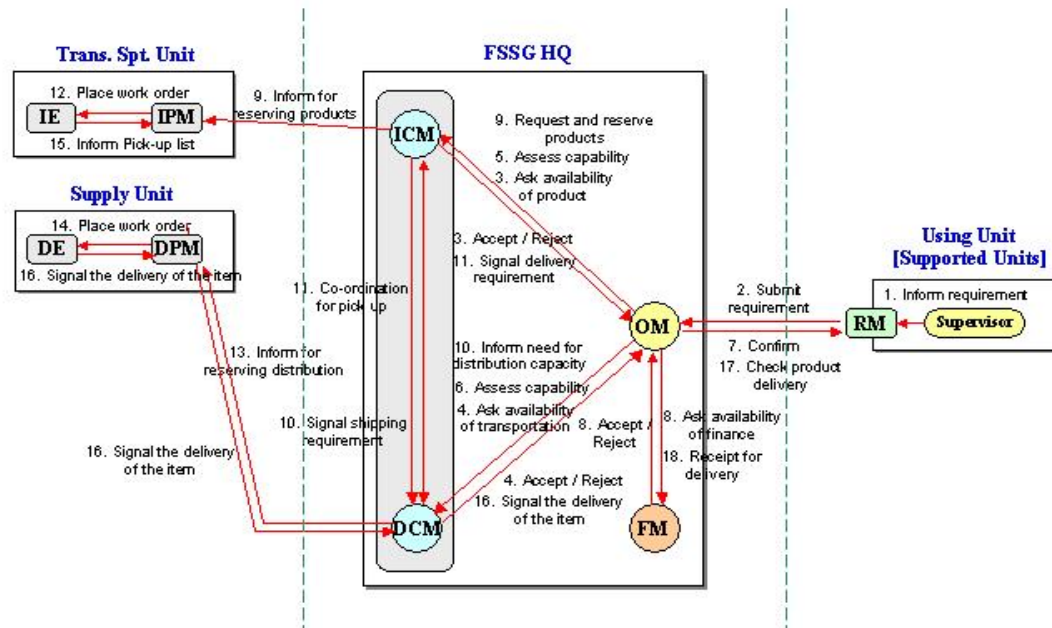
Figure 3.4: Information flow between the OA processes

Requests are generated "as occurring" and routed through the related personnel or "supervisor" for authentication to the centralized support group. The centralized support group is a combination of an ERP system and the management teams (human-in-the-loop). The orders received by the system are parsed and relevant data elements are distributed to the various Capacity Management (CM) modules (ICM, DCM, etc.). This information is also visible to the management teams based on which relevant decisions can be made.

Depending upon the availability of the services/products requested, the CM modules will signal the production management units with the relevant information. The production management units use this information to generate specific work orders, pick-up/delivery orders, etc. as required and transmit them to the execution units under their command. Upon receiving the services/products through the executing units, the using units signal the ERP system about the receipt. The ERP system then updates the inventory database and records this event in its historical database. The management teams have near real time information visibility. The ERP system maintains a comprehensive database of the availability of different products/services within its domain, which is continuously updated.

A detailed review of different interacting nodes mapped to the information flow will enable the identification of different relevant wireless technologies to specific segments between two nodes. The details can be found in section 3.4.

3.4   Node to Node Connectivity

Table 3.1 shows the node-to-node communication that occurs within the *Order Management (OM), Request Management (RM), Production Management (PM) and Execution (E) processes.* This table also identifies the different elements that are interacting and also the type of information that would be communicated (with the attributes and medium).

A number of sub-processes for the Product Order fulfillment (stocked item) are shown in Table 3.1. The distribution process, though generic, is captured within all the procurement processes. Table 3.1 does not show the internal information processing that occurs within a particular node before information is generated and passed on to subsequent nodes.

All the tables in this chapter are populated by inferring the information flows after looking into the sequence diagrams and the different use cases that have been developed for the individual processes, as presented in the operational architecture literature. We use these tables as our foundational building blocks for scientifically arriving at wireless infrastructure requirements.

The different processes shown are:

- ❑ Product Order Fulfillment process

    - o Stocked Item

    - o Non-Stocked Item

    - o Multiple source Item

- ❑ Distribution process – Embedded within the order fulfillment processes.

- ❑ Procurement Fulfillment process

Appendix [6.4] includes tables for Non-stocked item, multiple source items, distribution process, and procurement fulfillment process. Figure 3.5 captures the nodes for the product order fulfillment processes.
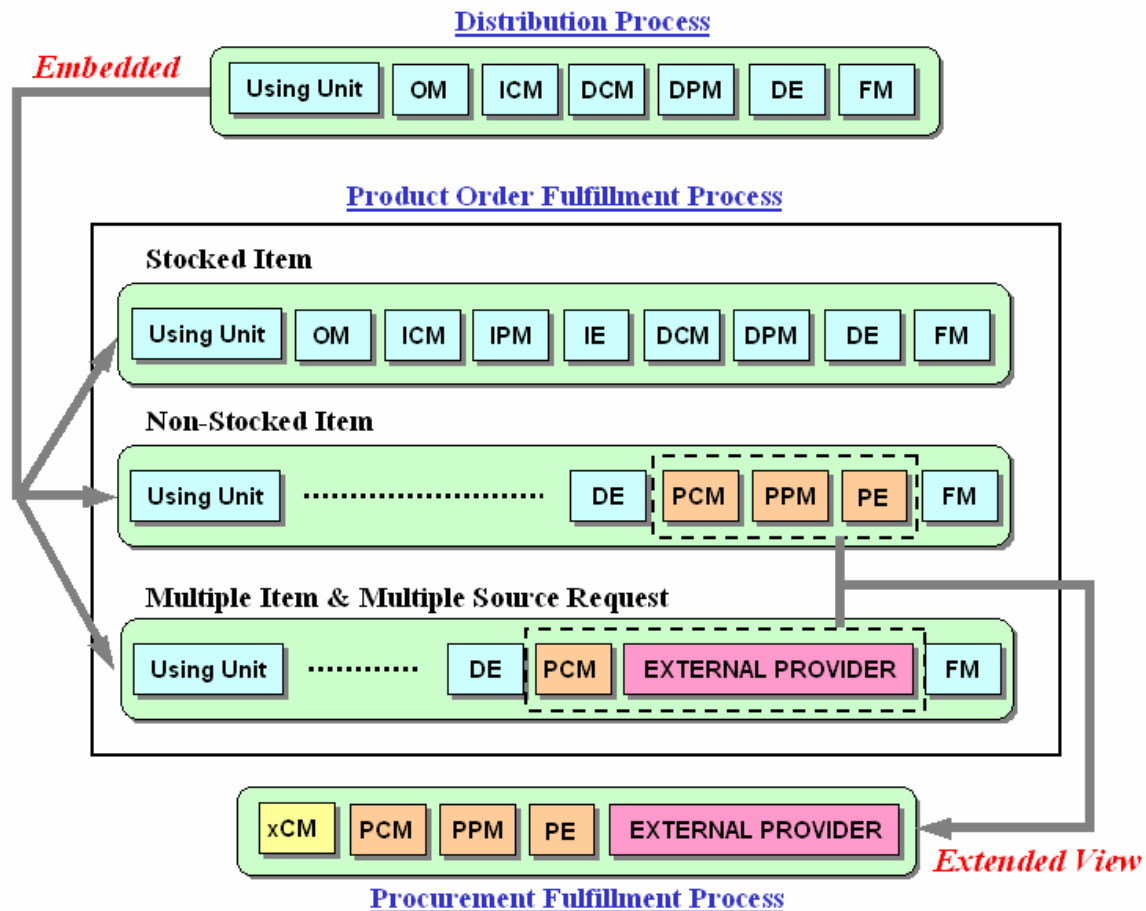
Figure 3.5: Nodes for the Product order fulfillment

3.4.1 Interpretation of the Tables

As mentioned before, we use software agent formalisms to analyze the information flows/requirements systematically.   Agent communication is grounded in speech-act theory. We have used the following terms from Knowledge Query Manipulation Language (KQML):

- Speaker – Process Originating a particular communication
- Listener – The destination module, where the information is received
- Performative – The action intended to be performed for a particular communication between two nodes [Kumara et al., 2003]
- Attributes –data elements that are transferred during communication
- Medium - the required mode of communication (for example voice, text, image, form etc)

ORDER FULFILLMENT: Stocked Item

Typical customer (defined as using unit) identifies a need for a product that must be fulfilled by the logistics chain (Garrison or Deployed). Product is stocked at the Intermediate Supply Activity (ISA). Product is on hand.

Table 3.1: Node to Node communication for Order fulfillment

Step	Speaker	Listener	Performative	Content Description	Attributes/ Media	Comments
1.1	Using Unit	Supervisor	Ask	Inform the requirement and ask for validation	Unit Identification, NSNs Quantity, Location, Expected time for replenishment. - **Text, Digital, Voice**	The request could be sent as an e-form. The location information is identified by the GPS enabled device and sent along with the form. The voice acts as a backup for human – human.
1.2	Supervisor	RM	Inform	After accepting the requirement	Secure signature - **Encryption**	Usually password encrypted
2.0	RM	OM	Inform	Submit and inform about the requirement on behalf of the using unit.	Request Identification + 1.1 - **Text, Digital**	In addition to the request form a request ID is automatically generated by the system which would be some digital information
3.0	OM	ICM	Ask / Accept	Ask the availability of the product and ICM agent either accepts or rejects.		
4.0	OM	DCM	Ask / Accept	Ask the availability of the Transportation for the distribution of the product and DCM accepts or rejects it.		
5.0	OM	ICM	Ask / Accept	Assess the capability of delivering the products if currently insufficient.		
6.0	OM	DCM	Ask / Accept	Assess the capability of making the distribution process available.		
7.0	OM	Using Unit	Inform	Confirm with the using unit by reiterating the requirement.	Request ID confirmation - **Text (short message) Voice**	Confirmation of the request can be achieved by sending the request ID back and forth with the customer.

Table 3.1: Node to Node communication for Order fulfillment (contd.)

8.0	OM	FM	Ask / Accept	Ask availability of finances FM either accepts or rejects.	List of materials, unit cost quantity, Total cost, customer ID Availability. - **Text, encryption, digital**.	The total cost for procurement is presented as an e-form. It is encrypted and sent for confirmation of availability of funds.
9.0	OM	ICM	Inform	Request for the products and ask the ICM to reserve the products.		
10.0	OM	DCM	Inform	Informs in advance the need for distribution capacity for the reserved products.		
11.0	ICM	IPM	Reserve	Inform the IPM agent for reserving the products.	NSNs, Quantity, Order ID - **Text, Voice**	The specific list of consignments is sent so as to enable the IPM to reserve these products.
12.0	ICM	DCM	Inform	Signal the shipping requirements		
13.1	ICM/ DCM	DCM/ICM	Inform / Accept	Co-ordination for pick up		
13.2	ICM	OM	Inform	Signal the delivery requirements	ETD (expected time to delivery) Constraints - **Text, Voice**	The requirements for delivery such as expected time POC is sent to the OM.
14.0	IPM	IE	Request/Commit	Place a work order to the inventory execution element to make the product ready for pick-up	NSNs, quantity, packing rqmts, Time to pick-up, Priority - **Text, Voice, Digital**	The work order that contains the consignments to be made ready for delivery can be sent again as an e-form. The priority is a machine generated digital code.
15.0	DCM	DPM	Reserve	The specific products and number of products are asked to be reserved.	Transporting unit ID, Time to pick-up, Location - **Text, Voice, Digital**	The identified products are listed out and sent.

Table 3.1: Node to Node communication for Order fulfillment (contd.)

16.0	DPM	DE	Request/Commit	Place a work order for the pick-up and delivery of the products to the DE.	Consignment Labels, Location, Destination location, Product List. - **Text, Voice**	The location from where to pick-up the consignment labels and product lists are sent using both the e-forms and image files.
17.0	IE	IPM	Inform	Inform the Pick up list packaging labels & configuration	The package Labels, confirmation - **Text, Voice, Image**	The packages once reserved are identified by their labels and the information is sent using image files.
18.1	DE	DPM	Inform	Signal the delivery of the item	Signal - **Text, Digital, Voice**	The consignments that are delivered can be identified by their labels and signaled back upon delivery.
18.2	DPM	DCM	Inform	Route the signal from DE to DCM		
18.3	DCM	OM	Inform	Signal item delivery to OM agent		
19.0	OM	Using Unit	Ask / Accept	Checks with the using unit if the products were received or not.	Signal, signature, Receipt - **Text, Digital**	The delivered consignment labels are sent and verified by the customer.
20.0	OM	FM	Inform	Receipt for delivery.	Invoice - **Text, encryption, digital**	An invoice for financial claims is sent using e-forms and encryption techniques.

3.4.2 Initial Observations

The analysis of Table 3.1 shows the required medium of communication for the different OA processes. Obtaining data from the USMC personnel regarding the frequency with which the requests are generated and the physical distribution of the elements in a deployed environment will help to estimate the volume of data exchanged. This will primarily influence the type of wireless communication network that has to be used and also the size of the required infrastructure.

Table 3.2 shows the communication media and the technical requirements for different OA processes. The approximate size of the data transmitted using each of the media is also computed.

Medium Definitions [OA-CD]

- "Digital" implies that the primary means of transferring information or data is via automated interface (e.g., publish-and-subscribe where transactions are published to a database and other applications subscribe to receive updates from that database; transaction-based where one application is available to receive transactions from another application as they occur. This does not imply that a human does not ultimately benefit from the information in some form. For example, the ultimate medium for a digital transaction could be in text form based upon interpretation of an automated system.

- "Voice", "Text" and "Image" imply that there may be direct human-to-human or computer-to-human interaction for the purpose of communicating information directly for human interface.

Table 3.2: Medium Requirements for OA Elements

	E-form / Text	Digital	Voice	Image	Location GPS Information
Request Management	*	*	*		*
Order Management	*		*		*
Production Management	*	*			*
Execution	*			*	*
Capacity Management	*		*		*
Requirements	Data Communications	Encryption / Decryption Module	Telephony Service	High Communication Speed	GPS
Data Size	~0.66 kbps	~ (1.3 * original data) kbps	~ > 50 Kbps	~ 600kb	~ 50b/sec

3.4.3 Data size calculations

Text: The text data is assumed to be generated from a handheld PDA with screen size 320 * 240 pixels (for e.g. HP ipaq). This equals twenty lines of text with thirty-three characters each (660 characters). Thus, the size of text-based message can be assumed to be 0.66 Kbytes.

Encryption: Standard encryption algorithms increase the size of data to 1.3 times original data.

Image: A colored image consisting of 256 colors generated from a 320*240 pixel hand held device would have a size of 600 Kbytes.

Table 3.3: Wireless Communication Technologies

	Personal-Area Network	Wireless LAN	Wide-Area Network	Satellite Network
Range	Up to 10 meters; Peer-to-peer	50 – 200 m; Campus size	Greater than 5,000 meters; nationwide	Nearly unlimited; Worldwide
Communication Speed	1 Mbps	4 – 11 Mbps	27-153 kbps	2,4 – 400 kbps
Technology	IrDA Bluetooth	802,11x	CDMA2000 1xRTT GSM GPRS	Iridium, LeoOne, NewICO, OrbComm, Skybridge, Spaceway, teledesic
Strength	• Low cost	• High speed Communication	• Wide Communication Range • Relative Low Cost	• Wide Communication Range • Security
Limitation	• Short Communication range	• Security • Relative short communication range	• Depend on Base Station • Security	• High Cost • Low Communication Speed • In-house Communication

The specific capabilities of the different wireless communication technologies and location services are listed in the Tables 3.3 and 3.4. Further details and technical specifications are detailed in the Appendix [6.5].

Table 3.4: Location Services

	Cell ID	EOTD, AFLT	GPS	A-GPS (Assist)
Accuracy	100-1000 m (Cell)	75-300 m	15-150 m	1-10 meters
TTFF (Time To First Fix)	< 5 sec	< 5 sec	10-60 sec	< 5 sec
Added Cost	None or very Low	Low	High	High
Application Area	Situation where neither GPS nor EOTD/AFLT	Dense urban, indoor and underground application	High precision needed in urban and rural environment	

4.0   Technical Specification of Wireless Technologies

This chapter focuses on the technical description and specification of wireless technologies. In order for USMC to implement wireless technologies, it becomes important to understand the technical aspects.   Moreover, these details will help in deriving the relationship between the OA information specifications and bandwidth requirements.

Enabling Wireless Technology exist today where the wireless transmission of information may take place between very small open gap separation distances (measured in microns). Likewise, wireless technology is also in use today that can be used to transmit and receive information between two points (measured in tens of thousands of miles).

Target wireless applications using enabling technology will depend on a number of important systems technology factors.   These factors, when known or available from public literature, have been included in this report. For example, important wireless communication factors described in this report are:

- Operating frequency,
- Bandwidth (data rates)
- Range
- Security requirements
- Memory capacity
- User density
- Power consumption
- Ease of deployment
- Ease of integration
- Weight, dimensions and ambience

Overall, this report researched a plethora of commercially available off the shelf wireless equipment and sorted the findings by using the following categories:

a.   Short Range Wireless Communications
b.   Long Distance Satellite Communications
c.   Cellular Communications

Summary tables for each specific technology category (Short Range Wireless Communications, Long Distance Satellite Communications, Cellular Communications) are included in Appendix [6.5].

Appendix [6.5] also contains information pertaining to wireless technologies used in identification & tracking (including RFID, RTLS, GPS, & Cellular based Tracking) and concludes by providing several business examples that utilize all of the above COTS wireless technologies.

5.0 Summary of Statement of Work

Task	Title	Description	Status
1	Background Research & Review OA Processes and Performance Measures		
1.1	OA Reference materials & training	The sponsor shall provide reference materials & training on the OA to Penn State personnel. The materials & training will facilitate an understanding of the OA that will permit insight into areas suitable for portable/wireless technology implementation.	Completed
1.2	Compilation of previous studies	The sponsor shall assist Penn State in compiling & reviewing any previous studies or other on-going DoD portable/wireless technology initiatives.	On-Going
2	Market Research & Recommended Processes to be Enabled		
2.1	Conduct market survey	A market survey will be conducted of commercial-off-the-shelf (COTS) and future developmental portable/wireless technologies that are/could be available to support the OA	On-Going
2.2	Identify OA processes to benefit from wireless technology	Based on an understanding of the OA and sponsor input, identify those OA processes that will benefit from COTS or developmental portable/wireless technologies. The identification of the OA processes will be based on metrics to be mutually agreed upon between Penn State and the sponsor.	Completed
3	Identify Key Data Elements & Information	For each process identified in Task 2, identify the key information required for both the execution and performance of the process to no lower than SCOR Model Level 4 logistics support.	On-Going
4	Determine Unique Military Considerations	Identify the unique military considerations that will inhibit or enhance the use of portable/wireless technology (e.g., deployability, environment, integration with current/future USMC systems). These considerations will include the availability of domestic and international bandwidth.	On-Going
5	Determine Feasible Solutions	Given the results of Tasks 2-4, recommend feasible portable/wireless technology solutions and architectures for these processes, mutually agreed to between Penn State and the sponsor. Solutions are further limited to no lower than SCOR Model Level 4 detail.	On-Going
6	Determine Impact of Implementation	Determine the impact of portable/wireless implementation on the attributes defined within the OA (e.g., reliability, responsiveness) as they apply to the selected processes. Where mutually agreed to between Penn State and the sponsor, provide recommended future development insertion, where applicable.	To be started

6.0 Appendix

6.1   Wireless Applications for Supply Chain Management
6.2   UPS and FedEx
6.3   Inventory & Warehouse Management through Wireless Communication
6.4   OA Tables
6.5   Technical Specifications of Wireless Technologies

6.1 Wireless Applications for Supply Chain Management – Report of Commercial Applications and the Implications for the U.S. Marine Corps

This preliminary report focuses on wireless technology, particularly the RFID systems, and highlights ways that they are being used in commercial supply chains. It concludes with a broader look at emerging wireless technologies and potential needs of the future US warfighter. <u>The current report does not yet address the parallels between commercial applications and US Marine Corps applications. This remains to be done through conversations with USMC personnel in the coming weeks.</u>

<u>The report is developed completely from the published literature</u>. Interviews with ES3, Wal-Mart, and ConAgra are anticipated. These contacts may, in turn, lead to additional personal follow-ups that will further illuminate the contents of the current report.

6.1.1 Introduction to wireless applications

Emerging technology solutions will introduce several disruptions to current supply chain activities. Within factories, networked computing is being replaced with wireless communications.   Inventory tracking, even during production, is transitioning from bar coding to RFID (Radio Frequency Identification) tags. Between factories and with customers, internet-supported communication and tracking is replacing paper and verbal communication patterns.   New developments in sensors (microelectromechanical systems) and miniaturization will   dramatically   increase   connectivity.

Today, we think about connectivity as a network. New technologies will change connectivity to a commodity – everything will be connected to everything else in some way. The challenge is twofold: (1) envision operations as they might look in 2010 and beyond; and (2) determine how best to navigate the transition from current patterns to ubiquitous computing and communications.

The USMC, in seeking to rationalize its supply chain, has begun the process. Sweeping changes enabled by technology will require changes to organizational structures and reporting requirements.

6.1.1.1 Inventory ID and tracking

Automatic identification and data collection (AIDC) applications use bar codes, radio frequency identification, magnetic strip, voice and machine vision systems, optical character recognition, and biometrics methods to identify and track inventory. By far, the most pervasive is bar coding.

Bar codes

For the past 25 years, bar codes have been the most common method used to track inventory. Bar codes are a line-of-sight technology that enables scanners to identify the product type when the code is oriented toward the scanner.   The success of bar code labels depends on the label's readability and its adhesion to the product [1]. For bar code labels made of paper, there are three critical factors to consider: temperature of the tagged item, the environmental temperature, and the label's intended use. Plastics challenge many currently available adhesives for paper labels. The ink used in bar codes also affects reliability, with some inks being particularly susceptible to sunlight (or fluorescent light).

In addition to paper bar code labels, they can also be made from ceramic, metals, embossed rubber tags and direct part marking. Ceramic labels work best in high temperature applications. More recently, on-demand thermal transfer systems have been used to produce crisp bar codes on custom-cut labels that withstand moisture, humidity, tear resistance, and high-pressure sprays and abrasion.

For applications that require lifetime part traceability, direct part marking is often used. General Motors, Boeing, NASA and others use this indented bar code to permanently mark their parts. Bar codes that are etched or dot-peened onto an item can only be read by an imaging (camera-based) scanner. This generally adds to the cost of such a system. Parts can also be direct marked by ink-jet or laser printing technology that can be read by traditional laser scanners.

RFID tag technology

In October 2003, the U.S. Department of Defense announced its Radio Frequency Identification Policy (RFID). RFID technology greatly improves the management of inventory by providing hands-off processing. The equipment quickly accounts for and identifies massive inventories, enhancing the processing of materiel transactions. In addition to reducing supply chain management and tracking needs, RFID will enable DoD to improve business functions and facilitate all aspects of the DoD supply chain.

The new policy will require suppliers to put passive RFID tags on the lowest possible piece part/case/pallet packaging by January 2005. Acknowledging the impact on DoD suppliers, the department plans to host an RFID Summit for Industry in February 2004. The RFID policy and implementation strategy will be finalized by June 2004.   The RFID policy and the corresponding RFID tagging/labeling of DoD materiel are applicable to all items except bulk commodities such as sand, gravel or liquids [2].

Some commercial warehouse management systems have gone wireless. The central premise of these systems is the inventory status in a central database is always current since wireless strategies eliminate "information float" – the gap between the time something is inventoried and when the database is updated [3]. RFID application to inventory tracking dates to the 1980s and allows for non-contact reading.   RFID is effective for manufacturing and other hostile environments where bar codes would find survival difficult.

A tag consists of an RFID chip and an antenna. There are three types of tags – active, semi-passive and passive.   Current developments are focusing on passive RFID since it is less expensive to manufacture and deploy [4].

Like bar codes, RFID tags offer automatic data capture. The antenna on the RFID microchip transmits the identification information to a reader that converts the radio waves returned from the tag into a form that can be computer-read. Such systems are not limited by the bar code's more traditional line-of-sight (optical) requirement. The RFID code can be read as long as the tag is within range of the reader.

Marks & Spencer has replaced bar codes with RFID tags on about 3.5 million of its reusable trays that it has in its refrigerated foods supply chain. The RFID tags reduce the time it takes to read multiple trays and containers stacked on a pallet by about 80%. A complete dolly or pallet with 25 trays can be scanned in a single pass through an RFID portal in five seconds with high accuracy compared to the 29 seconds it previously required using bar codes. Truck unloading has similarly been reduced with the move to RFID from 18 minutes with bar codes to three minutes with RFID tags [5].

Passive RFID tags draw power from the reader that sends out electromagnetic waves to the tag's antenna. Because of this, passive RFID tags are range limited to within about 10 feet of the reader. Active RFID tags, on the other hand, have a battery which runs the microchip's circuitry and which broadcasts a signal to the reader. Active tags can communicate up to about 100 feet within the reader. Semi-passive RFID tags are a hybrid. They draw power from the reader to communicate, but also use a battery to run the chip's circuitry. Table 6.1.1 summarizes their various characteristics.

Table 6.1.1: RFID Tags and Characteristics [6]

	Active Tag	**Semi-Passive Tag**	**Passive Tag**
Power Source	Battery on tag	Battery for chip operations; Radio wave energy from reader for communication	Radio wave energy from reader for operation and communication
Tag Signal Availability	Always on; 100 feet range	Only within field of reader	Only within field of reader; less than 10 foot range
Signal Strength of Tag	High	Low	Very low
Required Signal Strength from Reader	Very low	Low	Very high
Typical Applications	Useful for tracking high-value goods over long ranges. Example: Railway cars on a track		Useful for high-volume goods where items can be read from short range. Example: retail checkout

The price range for active tags is approximately $10 - $150 while the price for a passive tag hovers at around $1 each [7]. Though prices approaching 5¢ per passive tag have been touted, these prices are generally associated with very large volume orders, at quantities nearing 1 billion tags. A more realistic price for passive tags ranges from about 20¢ to about $1.00 per tag, with differences largely depending on durability.   Not all RFID tags operate equally, even when operating on the same frequency. Tag performance is been related to its characteristics.

Relationship between tag characteristics and performance [8]

- Tag sensitivity – Sensitivity is defined as the ability of a chip to be energized to provide maximum signal strength back to the reader. The greater the chip sensitivity, the longer the read range;
- Tag size – larger tags generally mean longer ranges;
- Tag shape – different tag antenna shapes provide different levels of performance

- Number of antennas attached to the chip – two dipole antennas attached to a single chip results in tag performance that is less sensitive to orientation, a particularly important feature in random reading environments;
- Speed – Rapid read rates increase the reliability of tag reads and are less likely to impose burdens on business processes. Today, read rates vary for RFID tags from as low as 20 tags/second to more than 1,000 tags/second;
- Tight tag staking – when stacked closely together, tags may interfere with one another. The best tags available today work effectively even when situated within one-half inch of one another;
- Interference – well-designed tags and readers perform effectively in "noisy" RF environments. Interference in such environments can compromise data integrity;
- Packaging – how tags are packaged and attached to assets influences read range and readability;
- Material the tags are attached to – metal and water-based materials are generally hostile to RIFD, negatively affecting read range. Short buffers between the tag and the asset for such materials have proven effective in reducing this problem. Water-based materials, for example, have been found to reduce the collection ranges by as much as 50%. The friendliest materials for RFID tags appear to be cardboard, clothing and plastic

Read-only and read-write RFID chips

RFID chips can be read-only or read-write, depending on the application. The tags use Electrically Erasable Programmable Read-Only Memory. An Electronic Product Code (EPC) identifies the object and all data related to that object is stored on a server on the Internet. The EPC system automatically links the EPC code with the correct database, giving near real-time and highly accurate data about the specific object.

Auto-ID – combining bar code and RFID

The Auto-ID Center located at MIT, has pioneered auto-ID tags and their protocols. The Auto-ID Center hopes to use the electronic product codes (EPC) to transition from bar codes. The EPC is basically a serial number, with a structure that follows the Global Trade Item Number (GTIN) guidelines. The EPC has a header and three sets of data: the EPC manager (28 bits), the object class (24 bits) and the serial number (up to 36 bits). See Figure 1. The EPC manager is most likely the manufacturer of the product; the object class is the type of product, and the serial number is unique to that specific item. A key difference between EPCs and traditional bar codes is that the EPC provides a unique serial number for every item in the system; whereas the bar codes only identify groups of products. Such one-of-a-kind EPCs, coupled with RFID tags, will enable complete visibility of individual items within the supply chain. See Figure 6.1.2. This will eliminate the need to perform inventory counts and will drastically reduce mis-shipments.

Figure 6.1.1: Electronic Product Code Example. Source: Auto-ID Center Technology Guide.

There is no guarantee that the EPC will be adopted worldwide, but the Uniform Code Council and the EAN International, the two main bodies that currently oversee bar code standards, are supporting it.

Figure 6.1.2: RFID tag with barcode from Checkpoint. Source: Auto-ID Center Technology Guide.

The Auto-ID Center has proposed EPCs of 64- and 96 bits. Eventually, there could be more. The 96-bit number balances the desire to ensure that all objects have a unique EPC

and the need to keep the cost of the tag down. The 96-bit EPC provides unique identifiers for 268 million companies. Each manufacturer can have 16 million object classes and 68 billion serial numbers in each class, more than enough to cover all products manufactured worldwide for years to come. Since there is no need for that many serial numbers at this time, the Auto-ID Center has proposed an interim 64-bit code. The smaller code will help keep the price of the RFID chips down initially, while providing more than enough unique EPCs for current needs [9].

RFID frequencies

Though the 13.56MHz band is considered 'global,' RFID tags operate at various frequencies, ranging from low frequency to microwave frequency. Table 6.1.2 shows operating frequencies for passive RFID tags.

Table 6.1.2: RFID Operating Frequencies for Passive Tags [10]

	Frequency range	Read range	Data rate	Typical uses
Low Frequency (LF)	125 KHz	Less than 0.5 meters	Slower	Access control; animal tracking; vehicle immobilizers; POS applications (SpeedPass)
High Frequency (HF)	13.56 MHz	1.0 meter		Access control; Smart Cards; Smart Shelves; item level tracking (airline baggage, library books)
Ultra High Frequency (UHF)	860 – 930 MHz	3.0 meter		Pallet level tracking; tote tracking; electronic toll collection (EZPass)
Microwave Frequency (uW)	2.45 GHz/5.8GHz	1.0 meter	Faster	Supply chain management; electronic toll collection

Due to varying government regulations, there are regional operating frequency differences for RFID systems. Geographic areas, such as Europe, North America, and Asia, have specified different operating frequencies for the EPC tags to operate. For example, tags designed for the North American market typically operate at 915 MHz. European tags operate at different frequencies, including 13.56 MHz, 800 1000 MHz (UHF) and 2.4 GHz frequency bands [11].

Problems with RFID technology

Radio waves are absorbed by water and are distorted by metal. CHEP, an international pallet and container company, is using RFID technology to track its assets through repair and inspection facilities. Most of CHEP's pallets are made of wood, a retainer of water. In addition, CHEP experienced problems with metal interference in its warehouses. The company was able to "design around these obstacles" by using a forklift mounted solution to minimize the metal interference [12].

The RFID system

In the Auto-ID system, a combination of tags, antennas, readers, and local computers ('Savants') provides a near real-time view of product status and location. The key components of the Auto-ID standard are: Electronic Product Code (EPC), RFID tags, Tag readers, Savant servers, Object Name Service (ONS), and the Physical Markup Language (PML). The EPC identifies individual products, but useful information about the product is written in a new, standard computer language called Physical Markup Language (PML). PML is based on the widely accepted, extensible markup language (XML), and is expected to become a universal standard for describing physical objects, processes, and environments [13].

An RFID system includes RFID tags, antennas, a reader, RFID middleware (to process incoming RFID signals), and supply chain execution (SCE) software. See Figure 6.1.3.
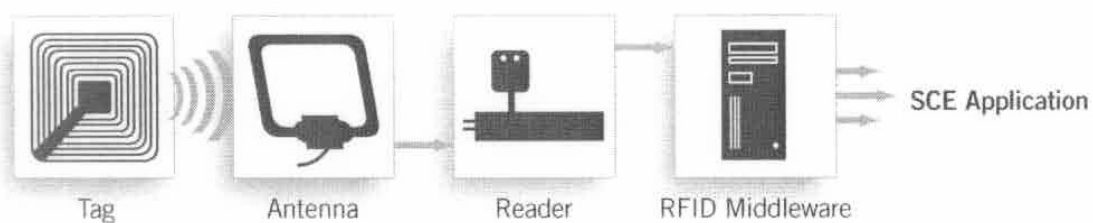
Figure 6.1.3: The RFID system [14]

One solution, the Sun™ architecture is illustrated in Figure 4. This architecture is intended to connect RFID technology (shown at the lower left of the figure) into existing enterprise resource systems (shown at the top of the figure). This particular architecture is based on open standards.   This, and similar systems, begin with the RFID tag and EPC. The readers detect the EPC data and the data is passed to the Savant which acts as an event manager that filters out extraneous EPC reads or events.

The ONS Server provides the IP address of a PML Server that stores information pertinent to the EPC. This is the unique data for each individual piece that is tagged with an RFID.   Data from the Savant is passed into the application infrastructure, or operations bus, either locally or over a WAN such as the Internet. From here, the data is made available to virtually any application that can make use of it.
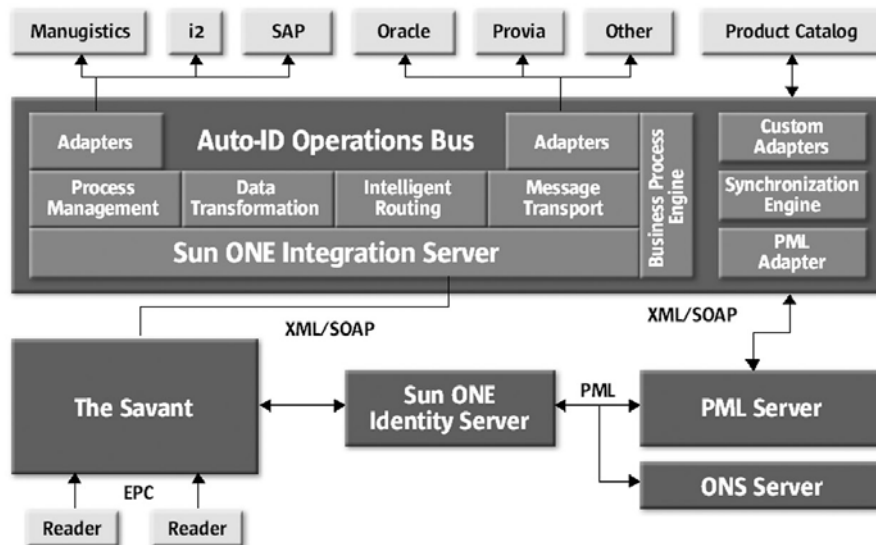
Figure 6.1.4: The RFID-enabled Supply Chain Execution Infrastructure Co-developed with Auto-ID Members [16]

Tag Readers [15]

RFID readers use a variety of methods to communicate with tags. The most common way to read passive tags at close range is called inductive coupling (the same technology used for key card entry at many companies). The coiled antenna of the reader creates a magnetic field with the coiled antenna of the tag. The tag draws enough energy from this field to send back its EPC. Readers cost about $1,000 today, but are expected to be available for $100 in volume later on. Readers are available which operate with tags designed for different regions.

The Savant [17]

In an environment where readers are picking up a nearly constant stream of EPCs, managing the data is a significant task. The Auto-ID Center has designed software technology called The Savant to act as the leading edge of this infrastructure. The Savant distributed architecture gathers, stores, and processes EPC data from one or more readers. Savants' also smooth data, correct duplicate reader entries, intelligently store and forward data up or down the chain, and monitor for events (low stock level, for example). Then, Savant servers pass data up to the ERP systems, through a full time connection, or synchronizing data on an "as needed" basis. The Savant framework consists of a set of geographically distributed servers. Savants are connected to RFID readers which continuously collect EPC data from tags, and feed this data to the Savant.

6.1.1.2 Commercial use of RFID tags

RFID systems have been around since World War II when the British mounted transponders to their aircraft to tell via radar whether incoming and incoming plane was one of their own, but until recently most applications were close-loop proprietary systems, often with items tracked within a specific location. Currently, RFID tags require external antennas to read them. The tags themselves cost about 30¢ and up per tag. Analysts believe that a more reasonable cost to achieve widespread commercial adoption is a target price of less than 05¢ per tag [18]. Recently Hitachi has reduced the antenna size and has embedded it into mu chips. Hitachi hopes to sell these for as little as 04¢ per tag by 2006 [19]. At this price, some interesting clients emerge, including banks that are considering embedding such a tag into currency to reduce counterfeiting.

Accenture analysts predict that by 2005, many retailers in consumer electronics, grocery, pharmaceutical and apparel industries will be the early adopters of RFID tag technology. Inventory management and out-of-stock applications are the highest priority for auto-ID technology currently. Others believe that the most rapid adoption of RFID technology will come in the automotive and aerospace sectors as these sectors try to deal with federal mandates [20].

One early adopter that is sure to drive RFID use is Wal-Mart. In June 2003, Wal-Mart Stores, Inc. urged its top 100 suppliers to deliver pallets and cases equipped with RFID by 2005. As a follow-up to this report, a visit to a Wal-Mart distribution center is planned.

In January 2003, Gillette ordered 500 million RFID tags from Alien Technology in Morgan Hill, CA [21]. Gillette justified its investment as a way to fight the "empty shelf" problem. Typically, consumers seeking to purchase consumer goods expect to have shelves fully stocked. Gillette is currently conducting field trials at Wal-Mart in Brockton, MA and Tesco's Cambridge, U.K. store. The company hopes to create an intelligent shelf that tracks customer purchases and alerts the company's order fulfillment system when supplies are running low. The intelligent shelf will also help the company to identify when abnormally large amounts of stock are being removed, such as might be the case with theft.

Another use of RFID tagging has been for high-value items or for tracking reusable containers. In addition, RFID tags are being implemented in some harsh environment applications commercially, particularly where the container is reused. For example, in Britain, the Carlsberg-Tetley Brewing Company is equipping its beer kegs with RFID tags to track them throughout their life cycle (production, delivery, use, recovery, and reuse). The life of these kegs is a minimum of 15 years and the tags must withstand the rigors of transportation, washing and rowdy pubs. Reusable container tracking is moving ahead faster in

Europe than elsewhere due to the stiff landfill taxes that discourage companies from scrapping containers [22].

Several devices support inventory tracking, including voice recognition systems, wearable devices, tablet computers and rugged PDA's. Standardization is increasing interoperability of devices. 802.11 and its derivatives are the standard developed by the Wireless Ethernet Compatibility Alliance, WECA. The shift to wireless for warehouse management is moving to the use of cell phones and PDAs via Internet access on either a real time or batch mode.

The real value of RFID lies in the strategic use of the information. Because RFID technology enables real-time, accurate data, it should be matched to applications where the underlying data are strategically significant to the operation.

RFID system adopters and participants

Though multiple industry uses can be identified, there are key players across the supply chain to watch from a commercial adoption standpoint. A July 2003 report summarizes some of the key tag and reader vendors, software players and early adopters. See Table 6.1.3.

Table 6.1.3: A Sample of RFID Players [23]

Tag Vendors	Reader Vendors	Software Players	Early Adopters
Alien Technology Corporation	Intermec Technologies Corp.	Descartes Systems	Boeing
Intermec Technologies Corp.	Matrics Inc.	EXE Technologies	CHEP
Matrics Inc.	Psion Teklogix Inc	GlobeRanger	Georgia Pacific
Phillips Semiconductors	SAMSys Technologies Inc	Manhattan Associates	Gillette
Savi Technologies	Symbol Technologies	OATSystems	International Paper
Texas Instruments	Tagsys	RedPrarie	Marks & Spencer
	Tyco Sensormatic	SAP	Wal-Mart

Within the RFID system, there has been more focus on the RFID tags than on other parts of the system, such as reader vendors or software players. RFID reader costs are actually a significant part of the system's costs. Several vendors make both readers and tags. Experts believe that most of these vendors are producing both tags and vendors to demonstrate their systems, but that in the future vendors will focus on one or the other.   For the systems to attain their potential, supply chain execution software companies must play a key role in the system. See Table 6.1.4 for a summary of vendors and their product attributes.

One supply chain execution software vendor, Manhattan Associates, is working across the system suppliers to provide customers with a "RFID-in-a-box" concept. The solution includes all elements needed to begin initial deployment and utilization of RFID technology, including RFID readers with two antennae per reader as well as a fixed number of RFID tags from Alien Technology Corp. to label and track goods. Customers will receive a limited license version of Manhattan Associates' Trading Partner Management (TPM) application, allowing them to enable their suppliers to remotely generate RFID tags and apply them to goods. It also will include remote Electronic Product Code (EPC) printers to print the RFID tags [24].

In addition to the vendors listed in Table 6.1.4, there are several systems integrators currently targeting the RFID supply chain application market, including Accenture, IBM Global Services, U.K-based Intellident and privately held (Xterprise).

Another emerging player, Sun Microsystems, in September 2003 announced an initiative for delivering the hardware, software and services that enable enterprises to link into the Electronic Product Code (EPN) Network. Sun's approach will enable enterprises to integrate real-time supply chain data seamlessly into their existing business processes and enterprise assets. The technology behind Sun's Auto-ID effort will be similar to the technology behind Radio Frequency Identification (RFID) tags. Specifically, Sun claims its software will deliver a dynamic federated service architecture that emphasizes reliability,

availability and scalability (RAS) for Auto-ID pilots and deployments. The proposed solutions also will include lifecycle services to maximize the value of Auto-ID deployments, helping customers proactively architect, implement, and manage IT operations in heterogeneous environments. Most of the company's EPC offerings will be delivered through the Solaris OE and Linux-based hardware platforms, setting the stage for transparent integration into the EPC Network [25]. The system architecture was displayed earlier in Figure 6.1.4.

Table 6.1.4: Characteristics of RFID Players [26]

Tag Vendors	Label Vendors Targeting RFID	Reader Vendors	Software Players
Matrics - Tags have superior read ranges, accuracy and reliability - Tags are orientation insensitive. - Compliant with Auto-ID Center's EPC. - Ultrahigh frequency (UHF) tags have broad adoption on pallet and case level - Is considering licensing its technology for tags **Alien Technology** - 500-million tag order from Gillette - Involved in Auto-ID field trials - Patented manufacturing process called fluidic self-assembly (FSA) will reduce per tag cost **Texas Instruments** - Company is large player in RFID space - Largest number of tags in real-world situations (as of June 2003) - Focus on high frequency tags will best serve item-level tracking	**Zebra Technologies** - Sponsor of Auto-ID Center - Partnering with Manhattan Associates **Avery Dennison** - Sponsor of Auto-ID Center - Strategic partner of Alien Technologies **Flint Ink** - Privately held manufacturer of inks and coatings - Developed a way to print inexpensive antennas using conductive inks - Collaborated with Scotland-based RT Circuits (which has proprietary technology for printing conductive materials) - Collaborated with Alien Technologies	**Intermec Technologies** - Offers wired and wireless automated data collection, RFID and mobile computing systems - Broad array of patents - RFID offering separate from its bar code reader technologies - Focusing on low-cost RFID pilots - Readers can read multiple forms and protocols **Symbol Technologies** - Background in bar code data capture - Actively partnered with several RFID tag manufacturers - Developing readers that will do both RFID and bar codes - Leading provider of auto-ID solutions using bar-codes in retail	**Manhattan Associates** - Judged to have superior position in RFID supply chain applications - Over 900 customers in supply chain execution, with aggressive pursuit of RFID space - Has developed "RFID-in-a-box" solution with Alien Technologies **SAP** - Worked with Metro AG in a pilot program to track assets using RFID at the pallet level

	KSW-Microtec	Matrics	
	▪ Has developed RIFD smart labels with integrated temperature sensors ▪ Has developed RFID labels that are washable and can be sewn or ironed directly into fabric ▪ German-based company	▪ Maker of both RFID tags and readers ▪ May have early advantage in reader sales since appear to have superior read ranges on their RFID tags ▪ Is considering licensing its technology for readers	

6.1.1.3 Other wireless applications to increase supply chain visibility

Some wireless applications can increase supply chain visibility using traditional cell-phone or other technology. ABF Freight, a $1Billion motor carrier, is using Nextel's wireless technology to improve productivity and customer responsiveness. Nextel's micro browsers are essentially cell phones with open connections to the Internet, a very cost effective technology [27]. ABF has been able to leverage a mass-produced cell phone for about $80 each, a cost which continues to decline each year. About 40% of the company's drivers are using these cell phones in approximately 52 terminals and in dock and yard operations in all nine of ABF's distribution centers. In fact, ABF is using wireless technology to manage three areas: street, dock and yard. It is doing this by using the phone's keypad to enter important information that is directly uploaded into ABF's mainframe. By linking this information to ABF's website, customers can see within minutes when a shipment is delivered. Micro browsers are also facilitating

tracking of shipments in the dock and in the yard, identifying where workers should put specific inventory.

Nextel actually has a continuum of wireless solutions that vary according to user needs. At it's simplest, cell phones allow for two-way communications between the head office (centralized data storage) and the driver (remote data entry point).   Walkie-talkie types of communications are the next step up the continuum, followed by two-way messaging facilitated by the Internet through hand-held device using a text-messaging format. Nextel also has a partnership agreement with @Road, a provider of fleet management solutions that uses an in-vehicle GPS unit [28].

RFID tags track more than inventory

ExxonMobil uses RFID tags to monitor gasoline purchases at pumps through its Speedpass payment system which operates at 134 KHz, considered a low-frequency application. [Note: A high frequency application would be in the 3MHz to 30MHz range, with many high frequency applications operating at 13.56MHz, generally associated with low-power industrial applications.]   The ExxonMobil Speedpass program combines customer payments and inventory tracking into a single system.

Similarly EZPass enables customers to pre-pay tolls and to pass through tollbooth areas without any contact. The RFID system automatically keeps track of tolls and payments.   RFID has also been used to track library books and the location of people (secure id's and prisoner bands).   These applications warranted the use of more expensive technology than that currently driving the adoption of RFID for retail and other commercial supply chain applications

6.1.1.4 Tracking at what level?

Tracking inventory can happen at the individual piece, the box, the pallet or the large-scale container. The level at which to track is important when considering the specific application. During the Gulf War, the Army had nearly 40,000 containers whose contents had to be manually verified, thus reducing total asset visibility and increasing time to process dramatically [29]. As the USMC deploys a large force to a remote location, it might send multiple cargo planes and/or ships laden with supplies of various kinds. Tracking all of these supplies at the individual level may prove cumbersome. A parallel in the commercial shipping industry exists.

In marine applications, for example, inventory is often tracked at the TEU, the Twenty- foot Equivalent Unit, or a 20-foot container.   Practically speaking, technology exists today that enables large port facilities to track inventory at the TEU level using Differential Global Positioning System (DGPS) and real-time locating system (RTLS) technology solutions [30]. The most common approach

is to track the location of the equipment that moves the containers. The equipment is tracked either by installing a DGPS receiver onto the equipment or by using RTLS tags. The challenge with these systems is that the tags must be associated with the actual cargo contents and often this is done manually or with bar codes. Both approaches involve a network of sensors on the vehicle. Automated container tracking decreases the non-valued added labor costs of searching for containers. It still requires that each container somehow be associated with its contents.

One current military application of pallet-level RFID tracking is the U.S. Transportation Command (USTRANSCOM), headquartered at Scott Air Force Base, Ill. USTRANSCOM acts as the single manager of America's global defense transportation system. During Desert Shield and Desert Storm operations, the command center moved approximately 504,000 passengers, 3.7 million tons of dry cargo and 6.1 million tons of petroleum [31]. Today, USTRANSCOM is using RFID tags at the pallet level to monitor air cargo bound for five U.S. aerial ports and two overseas (Ramstein Air Base and Yokota Air Base). The cargo being tracked includes mu-rations and repair parts.

USTRANSOM transfers information about the contents of the pallet to an RFID tag that is then mounted on the plastic mesh netting that secures the pallet contents. When the pallet is unloaded at its destination, a fixed location reader updates the DoD's information systems worldwide to identify the pallet and its current location. For locations that do not have fixed readers, a hand-held scanner is used.

Table 6.1.5: Savi Technologies and its Competitors [32]

Top Competitors	Other Competitors
Intermec Technologies	Atmel
Phillips Semiconductors	AXCESS
Texas Instruments	Brady
	Cooperative
	Computing
	Gemplus
	LXE
	Microchip Technology

The tags are supplied by Savi Technology, which has been awarded a $90 million three-year contract with DoD to provide RFID tags and related logistics software. Savi is one of several vendors working in this area. See Table 6.1.5.

Forrester Research estimates that the most common use of RFID technology currently is at the container level. Workers scan pallets at the distribution and warehouse stage rather than tagging individual items [33]. Retailers will change this dynamic as they adopt RFID to track high margin merchandise. The Gap, for

example, has realized inventory accuracy levels of 99.9% in their in-store trials of RFID at the piece level.

6.1.1.5 Return on investment issues for wireless

Not all wireless technologies are viewed equally. In fact, 51% of executives in Europe, North America and Australia indicated that they do not fully comprehend the value of wireless applications in their supply chains, many believing that the technology is not mature enough for full-scale deployment [34]. Security, network speed and geographic coverage top the list of barriers to widespread adoption of wireless applications. About 62% of U.S. corporations are planning to pilot or deploy a wireless wide-area data solution within the next two years. In-Stat/MDR estimates that wireless data users will grow from about 6.6 million at the end of 2001 to more than 39 million by 2006.

Table 6.1. 6: Examples of Wireless Implementations and ROI [35-36]

Company	Supply Chain Application	Approach	Estimated ROI
Cisco Systems, internet gear manufacturer	Incoming Logistics & supplier performance	Private, internet based hub linking manufacturers, distributors and component suppliers	Increased visibility and increased supplier performance
UPS, shipping	Incoming logistics	Using WAN in its distribution hubs. System includes package sorters with wireless ring scanners	Projected payback period of 16 months, with savings of $13.7M/year over the next five years estimated
Avail, aircraft parts distributor	Inventory management	Bar code labels of individual bins of aircraft parts tracked with wireless scanner; data transferred to ERP system	One year payback period for $100,000 project, Anticipated $1M/year in productivity improvements
Hewlett Packard, printing manufacturing facilities	Production	Wireless handheld computers work as an electronic clipboard to automate data collection and disseminate information to technicians; real time updates to HP data systems	Improved productivity 43 min/day/technician; Increased asset reliability 47%; decreased plant maintenance costs 25%.
Perishable Distributors of Iowa, frozen & refrigerated foods distributor	PRODUCTION & ORDER FULFILLMENT	Voice-activated system with headsets and computers on employee's hip convey directions on location of inventory and order fulfillment requirements	Decreased order errors 90%; increased productivity 20%; reduced new employee training time 60-70%.

6.1.1.6 Wireless technology to facilitate re-labeling with bar codes

Organizations that have multiple locations, many of which are remote, struggle to reap the benefits of ERP systems. This is particularly true of organizations that perform maintenance remotely. Effective field-maintenance capabilities are essential to continuous operations. Field maintenance has been supported by wireless cellular technology available commercially; private specialized mobile radio networks for companies in compact geographic locations; satellite communications for companies whose workers are located in areas not served by normal cellular coverage or by public packet-switched networks [37].

Current USMC shipping practices include bulk pallets that are then reconfigured into smaller batches for distribution. To successfully track individual items or smaller packages, new bar codes must be prepared as the larger pallets are resized. Bar codes are printed in much the same way as other labels. This requires that printers be located within close proximity to repackaging areas. Intermec [38] has developed a wireless solution to facilitate wireless printing of bar codes. In this way, repackaging areas can be located anywhere and printers can support them without network cabling. This reduces the complexity of repackaging and staging areas. The EasyLAN Wireless product uses Dynamic Host Configuration Protocol (DHCP) that allows the host system to assign a reusable IP address to the printer. This product is uses an industry-standard 802.11b radio and has 64 or 128-bit WEP encryption for network security.

6.1.1.7 Commercial distribution centers

Nowhere is supply chain visibility more important than in environments where goods are coming from multiple sources and then going to multiple locations. In fact, visibility is the foundation for supply chain efficiency, particularly as it relates to description and location and the make-up of incoming and out going shipments [39].

Inventory tracking is particularly challenging in commercial distribution centers. These companies bring together merchandise from a variety of suppliers and then redistribute it to several customers. Thus their order fulfillment and tracking is complex. Third party logistics providers indicate that the use of RFID technology will greatly reduce check-in/check-out time, unloading time, and time needed to record inventory. Commensurate reductions in labor needed, and associated reductions in errors, are also anticipated [40].

O'Reilly Autoparts [41], located in Springfield, MO, manages about 100,000 stock-keeping units (SKUs) in four distribution centers. This company supplies parts to auto repair shops and 515 retail outlets. For them, having the right inventory in the right place is essential. The company implemented NonStop's Score forecasting and replenishing software [42].

Jiffy Products of America [43], located in Batavia, IL, supplies goods to Home Depot, Wal-Mart, Walgreen Drug Stores and Lowes, among others. Jiffy implemented Exact Macola Software's live inventory and order entry modules [44] to help control its inventory. At its peak, Jiffy estimates that it turns over 40% of its warehouse inventory on a daily basis.

ES3 LLC in York, PA is another company using wireless technology combined with bar codes to track trailer-level shipments. The company is using WhereNet wireless location technology to provide instant visibility to all of its 1,900 trailer slots. ES3 is a supply chain services company that co-locates the inventories of multiple manufacturers. As a follow-up to this report, ConAgra, one of ES3's users, will be interviewed. A visit to ES3 is also in planning.

6.1.1.8 Comparing RFID and GPS for locational tracking

There is a distinct difference between applications using RFID and those using GPS to track inventory. Global Positioning Systems are generally used to track parts moving on a global scale. RFID, on the other hand, is used to track parts when a shipment and/or part passes a specific point on its journey. Generally RFID is most useful tracking items within the store, yard or warehouse [45].

One unique application of wireless tracking of "inventory" using GPS is by a commercial wine grower. Scan Control, based in California, has developed a GPS-based system that enables growers to track grape growth using mobile devices. This system allows workers to walk down a row of vines, input information, and through GPS have that information associated with specific latitude and longitude coordinates to link the information to a specific set of vines. This technology replaces the bar codes, which had been placed on posts at the start of each row [46].

6.1.1.9 Enterprise resource systems & wireless technology options

Within commercial applications, e-manufacturing has been a long-term goal. Such systems are characterized by an integrated plant floor that links individual operations within the plant, and mechanisms to link the plant floor with the broader enterprise, typically through enterprise resource planning (ERP) systems. SAP, Oracle, PeopleSoft or J.D. Edwards has developed the most common ERP systems. These systems are only as good as the data within them. Moreover, the data must be able to reach the point in the system where the information can be acted. Unfortunately this has often required significant company organizational reengineering to match organizational structures and communication patterns with the ERP architecture.

Recently, software products have emerged to help transport data back and forth among plant systems and between the plant system and the enterprise. This

Enterprise Application Integration (EAI) software has four general driving concerns [47]:

1. Reduce Work in Process (WIP): reduce the amount of inventory sitting around idle during production while it awaits the next processing step
2. Reduce Cycle Time: reduce the time it takes to produce a product from the time it is ordered;
3. Improve Asset Utilization: increase asset utilization by reducing the downtime on any given machine and by scheduling so that machines are operating at or near capacity; and
4. Develop Fact-based Decision-making: using information from the plant floor to trigger raw material ordering, scheduling, and order promising.

ERP systems have successfully helped enterprises improve their decision-making and thus, their bottom-line performance. However, these systems thrive on information that is accurate, up-to-date, and comprehensive.

6.1.2 Commercial use of wireless enabled ERP systems

Commercial users of wireless enabled ERP systems include garment manufacturer, VF Corporation that makes Lee and Wrangler jeans and Vanity Fair lingerie. VR Corp. is installing wireless LANs (Local Area Networks) in 200 manufacturing plants to link manufacturing to ERP systems. The company will also reach into its supply chain with retailers like Wal-Mart. VF Corp. is working with Symbol Technologies located in Holtsville, NY to supply the wireless LANs and RFID devices that will eventually link with the company's SAP system. The company is planning multiple input devices including mobile PCs, wearable computers, bar-code scanners and vehicle-mounted computers with bar-code printers [48].

Ford Motor Company is using WhereNet [49] wireless technology to support its build-to-order manufacturing strategy. Systems typically use a variety of inexpensive radio tags and cellular-reader systems to detect both the presence and location of the tags. Most of WhereNet's customers are large manufacturers that have complex products with expensive components that must be tracked during production. The Ford WhereNet initiative is producing savings at 30 Ford plants in North America and Europe by controlling line movement and reducing inventory [50].

Another company using RFID to eliminate human error associated with more traditional production systems is Johnson Control, located in Livermore, CA. This company produces automobile seats for New United Motor Manufacturers Incorporated (NUMMI), a joint production facility of Toyota and General Motors that uses the Japanese system of Just in Time Manufacturing. Johnson Controls first looked at bar code systems as a way to replace its manual approach, but found that the bar codes were susceptible to the dirty and abrasive conditions of

the production floor. Johnson is employing both read/write and read-only tags, depending on the seat production requirements (truck versus car). Using read-only tags, Johnson can quickly track the production of its pallets since a write procedure is not needed. Johnson uses the read-only tags to convey information about the car seat's configuration needs, thus helping inform the production line as a car seat proceeds along its length. This replaces the more traditional manufacturing process of batching like-featured seats together into single production runs.   The information in the read-only tag also helps during product testing by "telling" the test machines which protocol to use in establishing performance metrics. The system increases both productivity and accuracy.

6.1.2.1 Sun example of enterprise wide linking [51]

Sun has developed a demonstration project at its iForce Center in Menlo Park, CA, that uses and Auto-ID system. The hardware configuration is detailed in Figure 6.1.5. The company has implemented its Advanced Shipping Notice (ASN) process. Once a shipment has been sent, the customer is automatically notified that it is in process; the customer is alerted to the exact contents of the shipment. This is possible since the pallets don't have to be unpacked to identify their contents – the contents of each pallet are automatically recorded as the pallet passes through the loading dock door. In addition to notifying the customer, the data is also passed to an integration bus where it can be shared with other ERP modules.

The ASN application is built on the Sun™ Open Net Environment (Sun™ ONE). While the foundation software is built with Sun ONE software (integrated), software from other vendors can be used. In addition, software from iForce partners is also used.

Figure 6.1.5: Sun iForce Hardware Configuration Linking RFID System with Enterprise Resource System

6.1.2.2 RFID implementation issues

Recent trials of RFID tags using the EPC network suggest that implementation issues are critical to system success. One group suggests that in trials more errors resulted from processes (taking the forklift through the wrong door) rather than technology failures per se [52]. In reality, actual deployment is overtaking the trials. Since Wal-Mart has announced plans for its top 100 suppliers to be RFID compliant by 2005, attention is now focused at distribution centers. In this way, the emphasis is on pallet level tracking, and experts anticipate that item-level tracking will not be broadly adopted until nearly 2007; trials of item-level tracking are expected to continue.

Wal-Mart field trials suggest that tags costing 40¢ each can be justified on pallets for market basket items costing $1.75

6.1.3. Emerging wireless technologies

Table 6.1.7: Key wireless technologies used in computers, mobile phones and other devices [53]

	Purpose	Frequency	Range	Speed	Devices	Compatibility
802.11a	Wireless internet access	5 GHz	25 to75 feet indoors; range can be affected by building materials	Up to 54 Mpbs	Laptop computers, PDAs, cell phones	Not compatible with 802.11b, 802.11g
802.11b (Wi-Fi)	Wireless internet access	2.4 GHz	Up to 150 feet indoors; range can be affected by building materials	Up to 11 Mbps	Laptop computers, PDAs, cell phones	Other 2.4 GHz devices like cordless phones may disrupt connection
802.11g	Wireless internet access	2.4 GHz	Up to 150 feet indoors; range can be affected by building materials	Up to 54 Mbps	Laptop computers	Other 2.4 GHz devices like cordless phones may disrupt connection
Bluetooth	Wirelessly connect computer peripherals, such as printers, PDAs, cameras	2.4 GHz	Up to 33 feet (10 meters); range can be affected by building materials	720 Kbps	Printers, cameras, cell phones, PDAs, other peripherals	Other 2.4GHz devices like cordless phones may disrupt connection
GSM (Global System for Mobile Communications)	Digital cellular telephone system; most-used system world wide	900 MHz, 1,800 MHz, 1,900 MHz	Determined by host network	Determined by host network	GSM enabled cell phones, PDAs, pagers	Not compatible with CDMA, TDMA networks
3GSM	Third generation GSM network	1,920-1980 MHz and 2,110-2,170 MHz	Determined by host network	2 Mbps data rate	3GMS-enabled cell phones, PDAs, pagers	Not compatible with CDMA networks
GPRS (General packet Radio Service)	An interface overlaid on existing GSM networks to allow for user internet access	Determined by host network	Determined by host network	Theoretical maximum speed of 171 Kbps; reality is 40-50 Kbps	GPRS-enabled cellular phones and networks	Does not support CDMA networks
CDMA (Code Division Multiple Access)	Digital telephone system used mainly by U.S. cellular networks	800 MHz, 900 MHz, 1,700 MHz, 1,800 MHz, 1,900 MHz	Coverage area of host network	14.4 Kbps data rate; a revised CDMA standard offers 64 Kbps	Mobile phones on CDMA networks	Not compatible with GSM, TEMA networks

CDMA2000	Third generation CDMA-based network	Any existing band	Coverage area of host network	144 Kbps; future speeds are estimated as high as 4.8 Mbps	Mobile phones on CDMA2000 networks	Not compatible with GSM, TDMA networks
CDPD (Cellular Digital Packet Data)	System used to transmit data over analog cellular networks	800 MHz, 1,900 MHz	Coverage area of host network	19.2 Kbps data rate	Cellular phones, PDAs, pagers	N/A
TDMA (time Division Multiple Access)	Digital cellular telephone systems	800 MHz, 1,900 MHz	Coverage area of host network	74 Kbps to 120 Mbps data rates	TDMA cellular phones	Not compatible with GSM, CDMA networks

There is an evolving standard, 802.16 for mobile area networks [54]. It is currently being developed by the IEEE 802.16 Working Group as a standard for broadband wireless access that offers high speed/capacity, low cost, and a scalable solution to extend fiber optic backbones. The standard, published in April 2002, defines the WirelessMAN Air Interface. 802.16 support point-to-multipoint architectures in the 10-66GHz ranges, transmitting data rates up to 120Mbps. A base station connects to a wired backbone and can transmit wirelessly up to 30 miles to a large number of stationary subscriber stations. Some believe that the WLAN, operating like a hub or bridge, will add security to wireless networks through a series of switches. A series of access points provides user authentication and facilitates roaming between access points and subnets [55].

6.1.4 Wireless technology facilitates maintenance and tracks equipment mortality rates

Equipment does not fail at the same rate over time. Wireless monitoring of new or newly overhauled equipment is gaining popularity. According to SKI Reliability Systems of San Diego, CA, infant mortality in new equipment is nearly 72% of industrially installed equipment [56]. If this equipment could be monitored in its early use, problems could be identified and corrected more quickly. Using wireless technologies enables a rapid redeployment of monitoring equipment once the new piece of equipment is confirmed in working order.   This creates a time-efficient troubleshooting and maintenance strategy.

Michelin has begun a pilot program where RFID tags are embedded into tires to track possibly faulty tires. The program is in response to Congressional law mandating that tire makers more closely track tire performance [57].

Sears has equipped the trucks used by 10,000 service technicians with GPS 802.11 wireless LAN and packet data services supported by a five-antenna dome

located on the trucks. The configuration is detailed in Figure 6. The five antenna configuration includes:

1. An 802.11b wireless local area network
2. One antenna for traditional terrestrial packet data network, such s Mobiltext
3. One antenna for a more expensive satellite packet network;
4. An antenna dedicated to feeding the GPS signal to mapping software on technician laptops; and
5. A not yet activated antenna that will use a back feed channel on the GPS signal that will pass it to a transceiver in a small device on the technician's keychain. This is intended to pinpoint the technician's location.

Two companies, Itronix and Wireless Matrix, designed the system. With these wireless networks, technicians have better access to data. Sears anticipates a payback period of between two to three years.
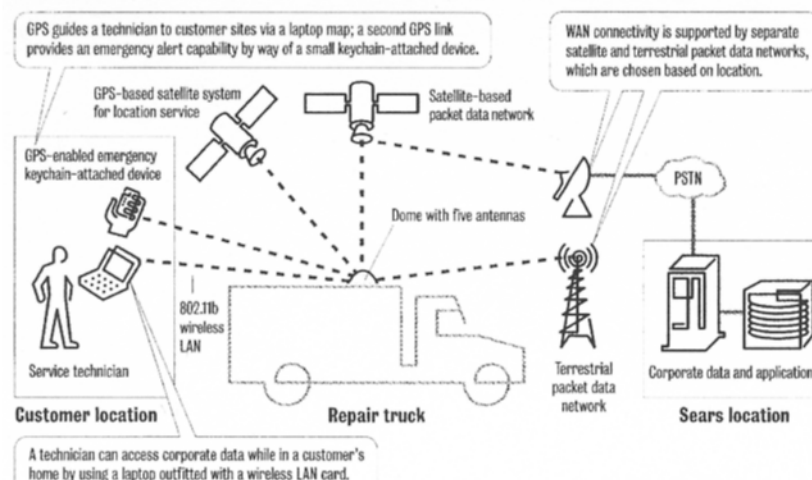
Figure 6.1.6:   Sears boosts employee productivity through access to multiple wireless networks enabled by a five-antenna dome situated on service technicians' trucks.

6.1.5 Wireless needs of the future warfighter

The 325th Airborne Regiment at Fort Bragg has already piloted mobile medical records in conjunction with the Telemedicine & Advanced Technology Research Center (TATRC) at Fort Detrick, in Frederick, MD [58]. Under this pilot project, each soldier in the unit was issued a digitized medical record on card about the size of the traditional dog tag. All of the 325th deployed to Iraq were provided with a secure hardware-independent flash memory card. Brigade medics were provided with hand-helds to read and write to the memory card, as medical treatment was needed. Future developments to make this system more robust include voice recognition systems and natural language processing.

Looking at US Army plans to equip its "Future Warrior," (See Figure 7) offers suggestions about how the warfighter of the future may require or benefit from wireless technology and communications [59]. Much of this combat gear is being designed under classified projects with Dupont, EIC Laboratories, Inc., and at MIT's Institute for Soldier Nanotechnologies. From a wireless point of view, many of the proposed developments that include sensing the soldier's health, location, and needs might effectively be supported by wireless technology. In such a deployed environment, the tradeoff will be between immediate notification of health status or changing needs with the ability of enemy forces to target the warfighter through such a transmission. Interesting to note, the advances in body armor will reduce the weight that soldiers carry into battle. This may facilitate wireless communication, as soldiers will need to tote batteries of varying sizes and weights, depending on their destinations. The U.S. Army plans to fund nearly $25Billion worth of research aimed at developing new ways to generate and store power. With today's technology, a typical brigade of 1,500 troops goes through 120 tons of batteries in a year – and that is with current technology needs. Super Soldier and wireless applications will increase power needs dramatically. This may well become a limiting factor to the deployment of wireless technology in the battlefield.

6.1.6 Power issues limit wireless applications

Power is the crux of mobility. For the past decade, battery technology has remained relatively stable, with most mobile applications using rechargeable nickel-based or lithium-ion batteries. These have only increased their storage capacity at a rate of about 8-10% per year [60]. In addition, these batteries are sensitive to their environment, particularly temperature. Intermec, in Everett, WA makes hand held devices for industrial applications. They have announced plans to use a methanol fuel cell from MTI MicroFuel Cells of Albany, NY in a device intended to track inventory. Experts anticipate that full commercialization of fuel cell products is unlikely with the next five to ten years [61].

One designer of fuel cells, Stephen Tang of Millennium Cell, has developed a boron-based fuel cell. Current cells in prototype can power a mobile phone for 12 hours talk time compared to the current 4 hours for an equivalent size battery. Even better, these fuel cells would be disposable just like today's alkaline batteries. The cell phone version will be contained in a package whose price target is $1.50 and Tang hopes to reach the market by 2005 [62].

Figure 6.1.7: Future warfighter

One company, Valence Technology, Inc. out of Austin, TX, has developed lithium-ion batteries that are paper-thin and similar to plastic. These batteries can actually be molded into different shapes and are being carefully assessed by hand-held device makers.

Another futuristic development is underway at SRI, International in Menlo Park, CA. Researchers there are working on artificial muscle transducers – actuators composed of inexpensive, easily produced elastic polymer materials that can be fitted into the boot of a warfighter to produce power as the soldier walks [63]. This power would then be cabled from the boot to portable devices, thus reducing the need for batteries. Currently batteries take up approximately 10 pounds of the overall 80-100 pounds of gear carried by the warfighter.

Perhaps one of the more interesting applications of wireless technology is the small island nation of Niue located in the Pacific. This island of 100 square miles offers an interesting opportunity to study low-power solar transmitters. Such applications may well suit the USMC in remote locations where portability is combined with erratic power systems and very remote locations [64].

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6.2 *United Parcel Services (UPS) and FedEx*

The following material is extracted/summarized from the references cited in 6.2.3.

6.2.1 United Parcel Service (UPS)

6.2.1.1 UPS Description

United Parcel Service (UPS) is an enterprise specializing in the collection and routing of parcels throughout the world. It represents an excellent example of a corporation actively in freight distribution and the application of logistics. In 2001, UPS generated incomes around 27.1 billion dollars and employed 358,000 people, 320,000 of them in the United States. Its service area covers 200 nations and handles 3.4 billion parcels per year; around 13.6 million per day, of which 2 million are carried by air transport (most of it in the United States). UPS handles about 55% of all parcels and express deliveries in the United States. Its infrastructure includes 2,400 distribution centers, 152,000 vehicles and 256 airplanes going to 391 airports in the USA and 219 abroad. Besides, UPS makes calls to about 356 planes on a contractual basis according to variations in demand, making it the 2nd largest freight airline in the world.

UPS has also a very important computer system and infrastructure that includes more than 150,000 computers specifically adapted to the needs of parcel collection (DIAD: Delivery Information Acquisition Device; introduced in 1989 and reached third generation devices in 1999). Each parcel handled requires about 250 data elements. This generates more than 30 gigabytes of numeric information per day transmitted over an optic cable network supported by satellite and wireless communication having a storage capacity of 9,800 gigabytes. This network is named UPSnet. The storage is necessary for the management of the very complex logistics of the several millions of parcels sent each week having different origins, destinations and recipients.

6.2.1.2 The History of UPS

UPS was established in 1907, in Seattle under the name American Messenger Co., to support the need for private messenger and delivery services. Since, phones and vehicles were not as common as they are today, messages couriers were quite useful for an urban population mainly walking or using crowded public transit. The company started as an enterprise specializing in the routing of parcels from department stores. One of the main factors that explain the success of the enterprise is the early adoption of logistics based on the consolidation of freight. It implies combining of packages addressed to a certain neighborhood onto one delivery vehicle to optimize transportation costs.

By the 1930s, the company expanded to Oakland and then California and took the name it is known as today. It inaugurated United Air Express, offering package air delivery throughout the West Coast. The consolidation system was still the key infrastructure for efficient delivery. This service was also expanded to New York City area, as UPS's service was still mainly intra-urban. From the 1940's to the 1960's, many elements favored the growth of the company; the shortage of fuel and rubber, caused by WWII, considerably reduced the usage of personal cars. The post-WWII expansion of suburbs in many metropolitan areas, where people needed extra delivery services especially where large shopping malls opened, also provided for growth. Simultaneously the consolidation of the service economy expanded the demand for parcel services.

A major change for the company occurred in the 1950s when UPS became a common carrier, receiving the right to deliver packages between any civic address within the territory this right was granted. However, it was not until 1975 that UPS was granted the right to be a common carrier for the 48 contiguous states and was able to offer second day deliveries throughout the United States. Shortly after, UPS expended from coast-to-coast and began to consolidate and expand its international services, initially in Canada and then Western Europe (Germany). By 1987, UPS was servicing almost every address in North America, Western Europe and Japan. This was done mainly be the establishment of high throughput distribution centers forming major air hubs. Since 1988, UPS operates its own airline; UPS Airline, the 9th largest in the United States and the 11th largest in the world. From the hub, UPS delivers to more than 391 national airports and over 219 international ones. By 2001, UPS was offering direct airfreight services to China. This totals about 1,000 flights per day.

The 1990s also represented an important stage in the logistics industry, namely through the growing number of transactions occurring online. The growth of Amazon-type commercial activities has been accompanied with a surge of parcels being shipped. Further, customers are able to track the location of their parcels throughout the distribution system.

6.2.1.3 The System of UPS

The UPS system is very particular and mostly aimed at servicing businesses since 80% of the traffic handled is business to business. To be effective, UPS relied on the efficiency of its distribution system. Reliability and efficiency are key issues in the establishment and management of freight distribution systems leaning on parcels. Optimal location for the hubs is sought, as well as the possible delivery routes to avoid unnecessary movements, congestion and assure timely deliveries. Every single parcel has to go through the UPS network regardless of its destination. It could be bound for the other side of the planet or addressed to the neighbor, the parcel will have to go trough the distribution system, which has a hub-and-spoke structure [Figure 6.2.1].

This distribution system involves three major functions:

Consolidation: The first step obviously involves the collection of parcels by trucks assigned to specific routes. To optimize the driver's effectiveness, study traffic trends and road conditions are continuously monitored to insure that the optimal path is taken. From his/her truck, the driver has access to an hand-held computer device (DIAD) that enables to capture information about each packages and delivery. This is essential to track a parcel or be alerted in any road change or unplanned situation. The parcels are then assembled at the closest distribution center.

Distribution: The distribution function works on a hub-to-hub basis, depending on the distance involved; the mode used between hubs is by road or air. Commonly, trucks are dominantly used for distances less than 400 miles (600 km). The main air hub is Louisville, Kentucky, which handles over 100 flights a day. In 2002, a new distribution center of 4 million square foot, called UPS Worldport, opened at the Louisville International Airport.

Fragmentation: This step is the inverse of consolidation, as parcels have to be delivered to each individual destination. Commonly, fragmentation is combined with consolidation as a delivery truck route can be integrated with a pickup route. This can be achieved only with a high level of control on the logistical chain.
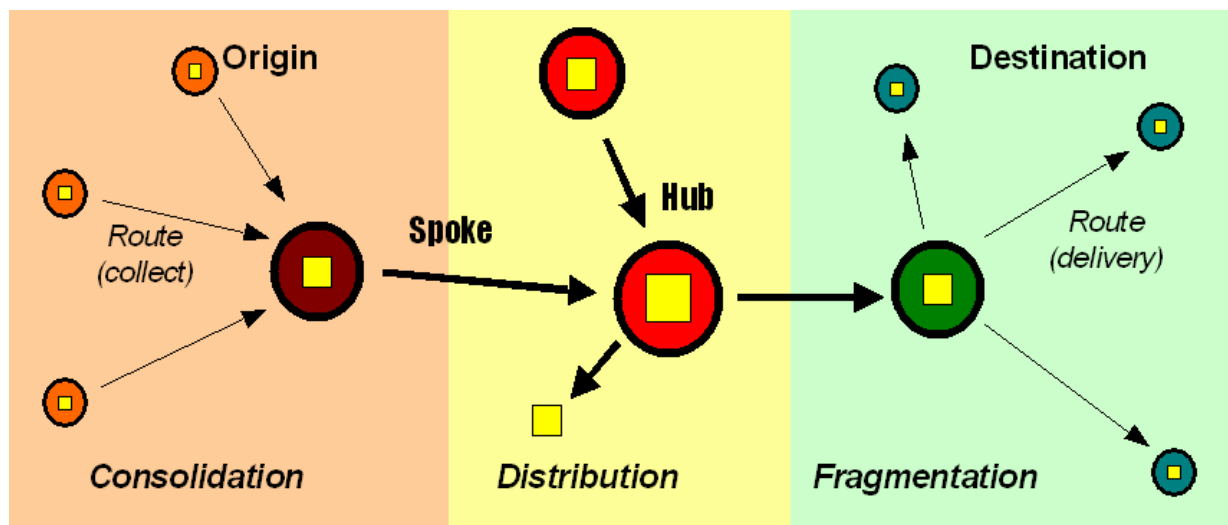
Figure 6.2.1: The Hub-and-spoke structure of UPS

•The first step is the pickup; specific routes are assigned and regular stops are planned according to a tight schedule. The package will inevitably be send to the hub for consolidation. The hubs are central sorting facilities located throughout the world. All the smaller local operating centers have to take their parcels to the nearest hub that can be considerably far since there are only 6 hubs in the world.
•At the hub, packages are unloaded and sorted according to the geographical location where they are bound. Consequently, all the parcels are divided to be loaded in the courier leading to the right destination.
•Deliveries are either made on the ground by cars and trucks.

Furthermore, UPS is investing massively in transport technology research. Innovations such as alternative fuels and electric vehicles are among their extensive testing programs, reduction in fuel consumption being their main concern. Engineers and geographers study optimal roads and driving speeds to enhance efficiency and reduce costs. In that regard technology, UPS is also working on computer software to simplify shipping red tape, optimize routing strategies and facilitate package tracking. The system also enables customers to locate and track their parcel directly from the Internet.

UPS is a textbook example of intensive research in transport geography. Optimal routing systems are essential to assure efficient delivery in only 24 hours throughout the world. Rigorous planning can also save considerable amounts in transport costs such as fuel, salaries, vehicle maintenance, etc. Theories such as the consolidation principle and the hub strategy are very important and useful in transport geography analysis.
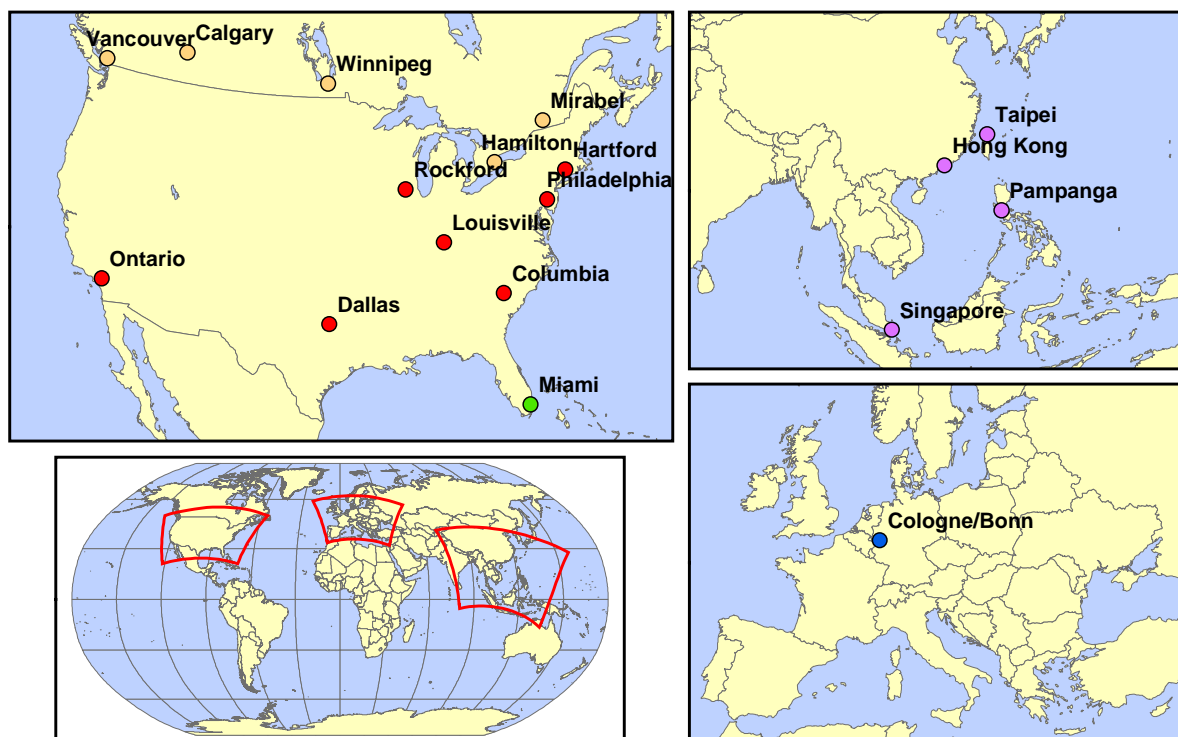
Figure 6.2.2: Major UPS Air Hubs, 2003

Louisville, Kentucky is the major air hub of UPS, which roughly corresponds to the demographic center of the United States. Any package bound for outside the United States is handled at this hub. Other hubs in North America are regionally oriented, except Miami that services the whole Latin America. Europe is serviced by Cologne/Bonn, at central location, while Asia is regionally divided between, Taipei, Hong Kong and Singapore

6.2.1.4 The Network and Hardware of UPS

UPS has a network infrastructure, which spans around the whole globe. In order to maintain a competitive edge in its industry UPS placed major emphasis on its information technology. Its annual investment in its IT-structure integration and supply chain application software is $1 billion.

Figure 6.2.3 shows a simplified topography. The network is divided into mainly three layers. The first layer consists of 14 mainframes with a capacity of 19,379 Millions Instructions Per Second (MIPS). The Mainframes are connected to Direct Access Storage Devices (DASD). The current storage capacity is 170 terabytes. The mainframes and DASDs are located in two data centers. The data centers are operating in two different US states however are able to take over each other's workload. This is very important for two reasons: One is that in case of a major operating failure in one of the data centers the other data center can take over the workload. The second advantage is regarding upgrades. In case of major upgrades, large parts of the data center might not be able to work. In such cases, the equivalent part of the other data center can take over the tasks. The DASDs provide data redundancy, which is important for security reasons. In case of fire or other third party, damage in one of the data centers the customer and company information will not be lost.

The second layer consists of 906 Mid-Range-Computers (MRCs). These MRCs are located in the major hubs that serve as a center for many smaller regional hubs. Again, physically closely located hubs can take over each other's tasks and provide backup facilities in case of failures. Each MRC serves approximately three Local Area Networks (LANs) as intermediary storage and processing units. Furthermore, these MRCs serve the newly developing UPS Online Tools. They represent the gateway to the mainframes and DASDs. This is very important for security purposes so that no personal computer has direct access to the data stored and processed in the data centers.

The third layer consists 2700 Local Area Networks (LANs), 135,000 workstations, and 211,000 PCs. This layer serves the main purpose of data entry and data retrieval for interaction with customers. In order to reduce the data entry, UPS utilizes the Delivery Information Acquisition Device (DIAD). The DIAD was developed by Motorola for a cost of approximately $100 million. It is the first and only hand-held computer in the industry to both collect and transmit real-time delivery information at virtually the same time. This device can read Bar-Code as well as Maxicode. Maxicode is a two-dimensional, machine-readable, package label code that is able to store up to 100 characters on a one-inch square. The utilization of the Maxicode enables UPS to reduce its data entry needs for shipping information to virtually zero. Software provided by UPS to its customers

is able to print all the shipping information on the Maxicode patch. This information can then be retrieved by the DIADs and directly transmitted to UPS. Furthermore, this system reduces the risk of data entry errors. Maxicode is even readable on wrapped or angled surfaces, which makes it much more user friendly then the Bar-Code system.

The three-layer system UPS utilizes has many advantages. It provides UPS with the ability to independently upgrade its layers, which gives them with a scalable system. The system is very fault-tolerant; its units are designed to take on larger capacities. In case of a failure of one unit, the other one has enough operating power to take over the tasks. This mirroring process furthermore operates as a backup system so that in case of data losses on one end the other can quickly pick up the task.

The three-layer design also provides a physical separation of the systems. This is important for data security reasons. For example, every terminal has to go first through the mid-range computers before it can reach the actual data processed on the mainframes and stored DASDs.
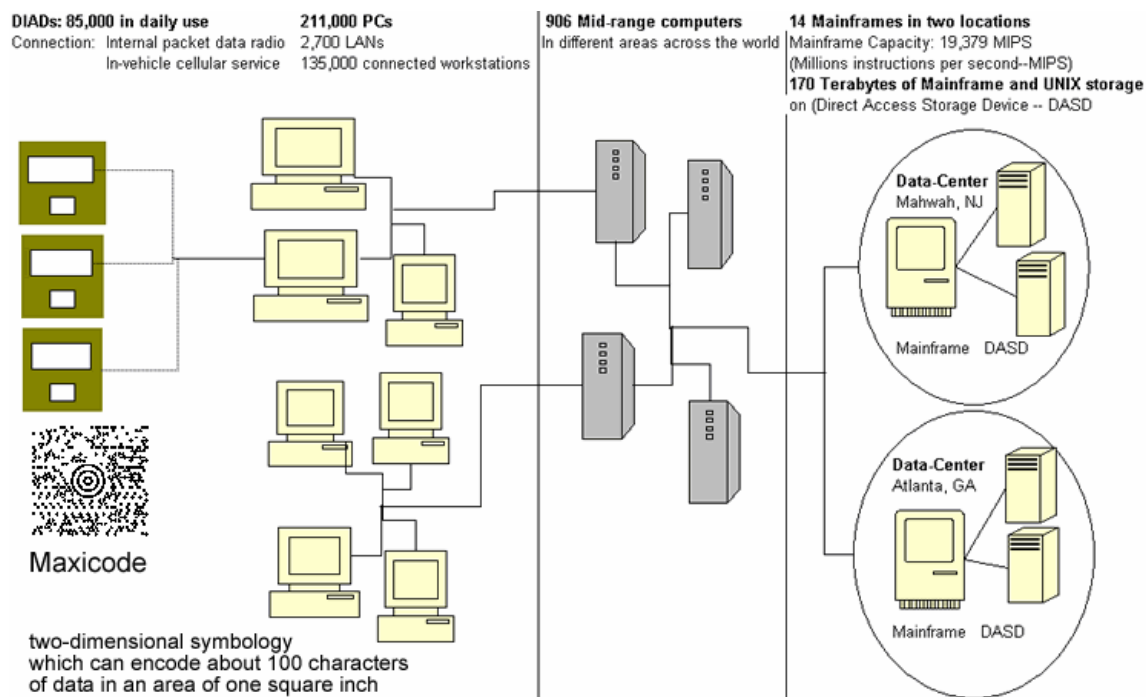
Figure 6.2.3: The Network Infrastructure of UPS

6.2.1.5 Database and software structure of UPS

Database

UPS possesses the largest DB2 relational databases in the world: Windward Data Center near Atlanta and Ramapo Ridge Data Center in Mahwah, N.J. built in 1995, Windward data center was designed to provide increased mainframe capacity and backup facilities for its sister data center in New Jersey. The two databases are self-sufficient and assist each other in ensuring uninterrupted service for UPS operations and also provide real-time access to package information. In the hierarchical architectural structure of UPS, the IBM mainframe based relational database technology supports both on-line transactions and batch processing in the day-to-day operation of UPS. It is supported by sub databases located on the mid-range computers. These mid-range computers provide a two-way communication. On one side it stores data and then transfers the datasets as a whole to the mainframes. On the other side they retrieve specific data from the databases stored on the mainframes to request of the user or application. This process spreads the processing power over the whole information infrastructure so that the mainframes as central units are not over utilized.

International Shipment Processing System

The International Shipments Processing System (ISPS) and the Operations System (OPSYS) are designed as internal information sources as well as a source for the customers to track UPS packages around the world. This system provides electronic information about the shipment stage prior to its arrival. Users of the system can monitor the precise status and location of packages. Information such as when a package arrived at a ramp or customs office and information about the approximate departure are available. It furthermore provides interaction with customs. Documents and forms can be filled in and signed online to speed up the clearance procedures. It also stores the history of prior shipments so that delays due to inaccurate filled in customs information could be prevented in the future. This system has an online billing ability. Not only will the bill be created online but also other duties and taxes can be directly paid through UPS.

This system is heavily based on its relational databases (DB2) technology located on the mainframes. It is furthermore supported by remote site sub-systems based on PCs, LANs and bar code, and Maxicode technology. These systems are widely linked through the Internet using standard TCP/IP protocols. Security standards like Secure Socket layer technology is used to provide a protected transaction of the data.

The benefits of this system lay in tremendous transit time reductions, the improved reliability of the shipment and total cost of service. It also reduces manual entry of shipment and custom information.

Automated Tracking System

The UPS Automated Tracking System (ATS) is an interactive voice response application that uses natural language speech recognition technology to provide fast package tracking over the telephone, accessible through UPS free-toll number. UPS ATS interfaces with the massive UPS database to reply to customer inquiries with a wide variety of responses, including the date and time of package delivery, the location of the package. For more specific requirement, UPS customer service representatives are available to callers by pressing.

As an architecture structure UPS uses Periphonics hardware together with Nuance Communication conversational speech recognition technology to transfer the voice request to a digital format. Then data is accessed through CICS (Customer Information Control System) an online transaction processing system that runs on the IBM mainframes.

The benefit of the system is that it not only saves time of the callers, but also frees the representatives for more complex inquiries.

Automated Pickup System (APS)

The UPS Automated Pickup System is another manifestation of the natural language voice recognition technology. Through APS, a regular or repeat customer can order package pickup for next-day delivery by telling the service his or her telephone number. APS would then quickly search the UPS database for the caller pickup address and closing time. After the data is located, a computer-generated voice using text to speech technology states the information for verification. After the address is verified, the pickup time and number of packages will be established. A customer service representative will assist the caller if the closing time or shipper number of the pickup address cannot be verified.

The architecture structure UPS applies here is similar to its Automatic Tracking System: Periphonics hardware and Nuance Communications conversational speech recognition technology. The system would then use customer telephone number as the key field to search for other information in the relational database.

The benefit of using APS is that it greatly reduces the customer pickup request time from 3.15 minutes to 90 seconds, thanks to the large capacity of the UPS APS interactive voice system, which is capable of handling 25,000 calls per day.

6.2.1.6 E-commerce of UPS

UPS is expanding far beyond traditional package delivery. It offers Internet-based and brick-and-mortar companies complete solutions for rapidly launching and succeeding in e-business.

UPS Online Tools

Starting from April 6, 1999, UPS has extended its aggressive deployment of innovative electronic commerce solutions by announcing its Online Tools. E-commerce vendors and systems integrators can use UPS Online Tools to seamlessly link their intranets and Internet websites with UPS.

The main features of UPS Online tools include:

Enhanced Tracking Shippers and their customers can track packages using their own internally generated reference number, (e.g., a Purchase Order number). By embedding UPS, tracking functionality into a Web site improves customer service from UPS aspect. Moreover, for a web merchant, this keeps its customer coming back to its site to check order status, which provides opportunities for further sales and marketing.

UPS Signature Tracking allows approved customers to track packages and receives the most complete proof of delivery available. Customers will receive the digitized signature of the person who signed for the delivery, the full delivery address, C.O.D amount collected, and the reference number associated with the delivery-all the elements needed to create an official proof of delivery to present to their customers to expedite payments.

UPS Shipping Tool-allows customers who ship at least 50 packages a day to enable all their employees to create and print shipping labels from their desktops. Customers can customize the interface and control which services and features are available to specific groups of employees. This tool also makes it possible for businesses to share information such as address books, shipment histories and tracking information across internal systems.

Easy to integrate-currently, the UPS OnLine Tools are available in both HTML and XML formats, which can be downloaded from UPS website. Specially, offering the tools in an XML standard will make it faster and easier for UPS customers to integrate shipping functionality into their own systems, and will provide them with more flexibility and customization. For instance, users can add delivery confirmation into an invoice without opening an additional application. Up to now, more than 60,000 businesses have licensed UPS OnLine Tools.

E-Document Exchange

The e-commerce has changed the way people handle paper-based documents. Would this be a problem for UPS as less people choose to send their file packages through physical delivery? No. Introduced in June 1998, UPS Document Exchange enables users to immediately ship over the Internet anything that can be contained in a digital file, including documents, images and software. But people might ask that since they can attach the files through emails, why bother UPS Online Courier?

The reason is as follows:
UPS Online Courier is able to send any file format with a minimum of 128-bit encryption. Only those who have the password to receive those files can read them. Many email servers have limited file size restriction. With UPS OnLine Courier, people can send e-Packages up to 70MB in size without the limit of SMTP (firewall). UPS Online Courier provides instant delivery notification, so when your intended recipient(s) pick up their e-Packages; an email notification is immediately send back to you.

6.2.1.7 Logistical Development and Integration of UPS

Over the last few years, UPS has shifted its attention at providing new distribution services and Internet-based activities. The UPS web site, which went online in 1995, is one of the most visited commercial site on the Internet and received on average 4 million tracking request per day in 2000. The emergence of e-commerce is a significant growth segment of the company, as it handled more than 9 million parcels a day from online transactions using UPS as a freight forwarder. For instance, since 1995, the creation of UPS Logistics aims a closer integration of the supply chain of clients, an activity expanded by online parcel management where clients can use the Internet to call for pickup and keep track of deliveries, for which UPS is an acknowledged leader. Theoretically, UPS could ship parcels anywhere around the world in 24 to 48 hours, the only impediment being the custom procedures of the destination country.

The logistical expertise developed by UPS over the years thus represents a major growth segment of its services. These services cover a wide array of logistical activities including quick air or inexpensive ground delivery, global trade financing, Web retailing and call centers, warehousing and supply-chain management. The company developed strategic alliances with major manufacturers and distributors where UPS takes over the management of the supply chain. Even large multinational corporations have difficulties managing their complex supply chain which globalization processes have tremendously expanded over the last three decades. In early 2000, UPS Logistics undertook a strategic alliance with Ford, under which it will manage the distribution of all Ford's vehicles produced in North America from factories to dealers. The goal is

to reduce by 40% the time required for such deliveries, mainly through an optimization of rail and road carriers and thus reduce transportation, distribution and inventory costs. A similar agreement was reached with Hewlett Packard, Nike and Nokia, where UPS Logistics will manage parts of, if not their whole supply chain.

6.2.2 Federal Express (FedEx)

6.2.2.1 FedEx Corporation Inc.

Fred Smith founded FedEx Corp. in 1973. It has been quoted as the inventor of the express transportation industry and customer logistics management. During 27 years of operation, FedEx earned a myriad of accolades and won over 194 awards for operational excellence. In 1983, FedEx became the first US company to achieve the US$1 billion revenues mark within a decade without corporate acquisitions and mergers. Today, FedEx is the largest express transportation company with about 30 per cent of the market share.

Initially, FedEx grew out of pressures from mounting inflation and global competition, giving rise to greater demand on businesses to minimize costs of operation and to improve customer service. For many businesses, physical distribution costs often accounted for 10-30 per cent of their revenue. Demand for lower costs, and fast and reliable service became a universal plea, giving FedEx the opportunity to leverage IT to respond to the emerging market needs (see Figure 6.2.4). Later, the Internet provided an inexpensive and accessible platform upon which FedEx saw further opportunities to expand its business scope, both geographically and in terms of service offerings.
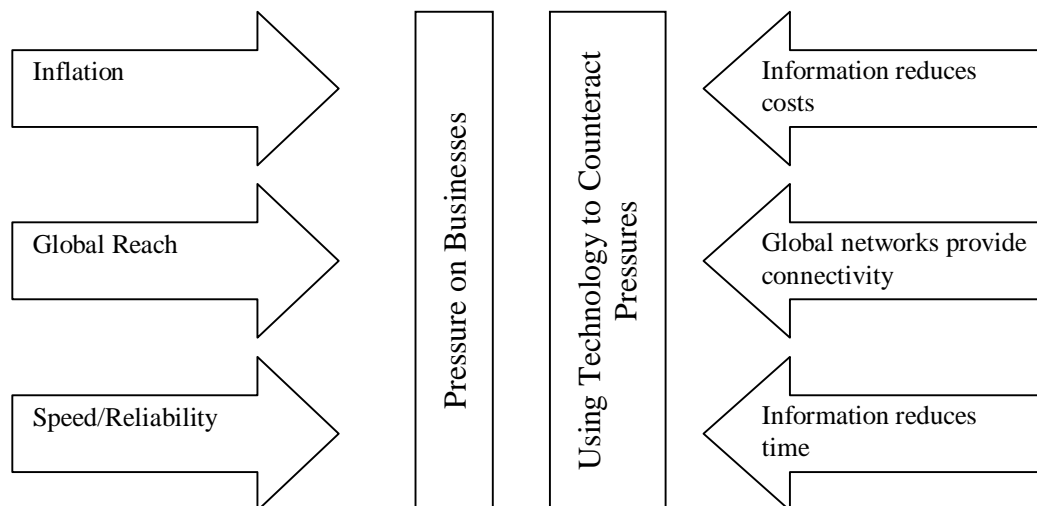
Figure 6.2.4: Using Technologies to Stay Competitive

The Internet has spurred the globalization of business and the evolution of electronic commerce. As companies in every country sought to establish overseas arms to take a share in the world's expanding wealth, FedEx had strategically positioned itself to provide the physical transportation needs from anywhere, to anywhere, around the globe.

The successful transformation of FedEx into an e-business has been aided by recent restructuring of operations to better serve the needs of its customers. In

January 2000, the company re-branded all its subsidiaries, as shown in Figure 6.2.5.
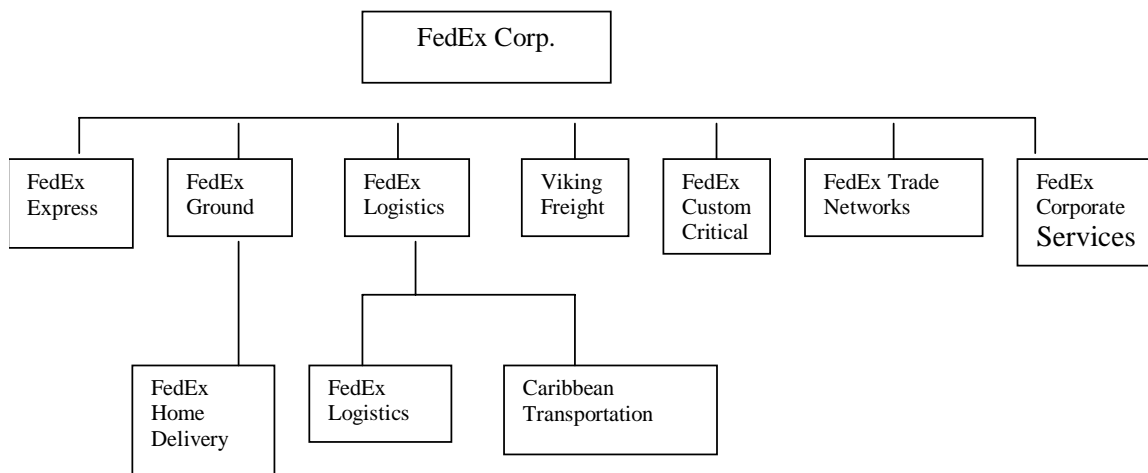
Figure 6.2.5: FedEx's Organization Structure

FedEx Express (formerly Federal Express) is the world leader in global express distribution, offering 24-48 hours delivery to 210 countries that comprises 90 per cent of the world's GDP. It has a fleet of 45,000 ground vehicles, 650 planes and 43,000 drop-off locations. The company currently handles more than three million shipments per day.

FedEx Ground (formerly RPS) operates in North America and provides business-to-business ground small-package delivery in one to three days. The company owns 8,600 vehicles and employs 35,000 people including independent contractors. It handles 1.5 million packages per day. In January 2000, FedEx Home Delivery was launched as a new business undertaking within FedEx Ground to address the growing e-tailing market.

Viking Freight is a less-than-truckload freight carrier in the western United States. The company employs 5,000 people, manages a fleet of 7,660 vehicles and 64 service centers and ships 13,000 packages per day.

FedEx Custom Critical (formerly Roberts Express) is a surface-expedited carrier for nonstop, time-critical and special handling shipments. The service offered has been likened to a limousine service for freight. In 1999, the company handled more than 1,000 shipments per day. Urgent shipments can be loaded onto trucks within 90 minutes of a call and shipments would arrive within 15 minutes of the promised time 96 per cent of the time.

FedEx Logistics (formerly Caliber Logistics) provides customized, integrated logistics and warehousing solutions worldwide. FedEx Logistics (the brand name) is the parent company of FedEx Logistics and Caribbean Transportation.
FedEx Trade Networks was formed in February 2000 to provide customs brokerage, consulting and trade facilitation solutions.
FedEx Corporate Services was formed in January 2000 to bring together the sales, customer services, public relations and IT resources

6.2.2.2 The Systems Architecture of FedEx

FedEx's information systems network evolved simultaneously with the evolution of information technology. Initially, systems and networks were developed to improve internal operational efficiencies. Subsequently, FedEx saw great value in sharing the information it held in its central database systems with its customers, to help them improve their business performance. By constantly exploiting new technologies, FedEx built in-house expertise in providing solutions to its customers to enhance their business processes. The success of FedEx is directly related to its elaborate network of LANs, WANs and VANs that form the central nervous system for its transportation and logistics business. But of equal importance is the in-house network of IT expertise that has grown with the business.

The Data Centers and Systems that Support the Hub-and-Spokes Model

Originally, systems were developed as an aid to more efficient management of its express delivery business. The transportation logistics information system was called the Customer, Operations, and Service, Master On-line System (COSMOS). This was the first centralized computer system in the industry used to keep track of all packages handled by the company. COSMOS maintains data on package movement, pickup, invoicing and delivery in a central database at Memphis headquarters. A barcode is attached to each parcel at the point of pickup and scanned up to 20 times (for international shipments) en route, at each stage of the delivery cycle.

The Global Operations Control Center (GOC) houses huge boards on the walls that track weather patterns and the real-time movement of FedEx trucks and aircraft. New systems have also been introduced to predict with greater accuracy the amount of inbound traffic. This allows FedEx to prioritize the hundreds of variables involved in the successful pickup, processing and delivery of a parcel. The GOC not only coordinates the sort-and-route logistics of shipments in the US, it also does so for the international flights. COSMOS and the GOC were ideally suited to the hub-and-spoke concept, as shown in Figure 6, which was pioneered by FedEx and later adopted by other carriers.

The Internet allowed further refinement of the COSMOS system. Whenever new information is entered into the system by FedEx or by customers through the

Internet, all related files and databases are automatically updated. For example, when a FedEx customer places an order through FedEx. COM, the information finds its way to COSMOS. An electronic mapping toll called Route Planner helps plan efficient pickup and delivery of orders from the customer. A product movement planner schedules the order through the company's global air and courier operations. The COSMOS system handled 63 million transactions per day in 1999.
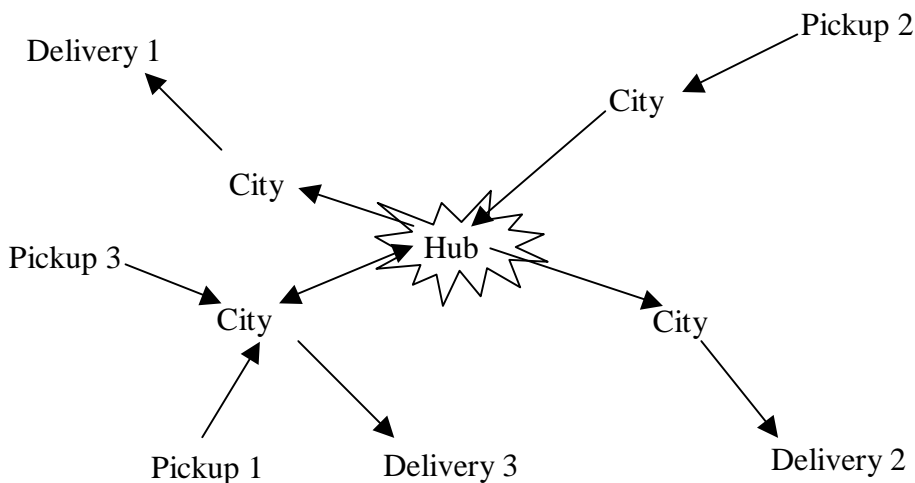
Figure 6.2.6: FedEx's Hub-and-Spokes Model

A Data Warehouse program made up of various systems applications and developed by FedEx enables any department within the company to access and compile data and reports that are needed to run their operations and improve service levels to internal and external customers. These systems are built around the mainframe and the client/server and distributed systems architecture.

COSMOS: Real-time package tracking

COSMOS (Customer Operations Service Master On-line System) is a computerized package tracking system that monitors every phase of the delivery cycle at Federal Express. FedEx employees constantly input information into COSMOS by several means.

Customer service representatives enter shipping information into COSMOS through computer terminals, alerting the dispatcher closest to the pick-up or delivery area. Dispatchers relay pick-up and delivery information to the courier via DADS, small digitally assisted dispatch computer systems found in all courier vans.

Hand-held computers, called Super Trackers, are used to scan the progress of the package an average of 5 times from pick-up to delivery. Couriers simply scan the bar code on every waybill with their Super Tracker, at every stage of the

delivery process. Scans are performed at time of pick-up, on arrival at the origin station, at the final station, when placed on the van of the courier's route and at delivery. Super Trackers retain and transmit package information such as destination, routing instructions and the type of service requested.

Once a courier returns to the van, the information is downloaded from the Super Tracker to DADS, which updates the package location in the COSMOS system. Thus, a customer can find out at any time exactly where their package is and when they can expect delivery, whether they call Customer Service or track the package themselves on the FedEx Web site or using FedEx Ship software.

Constant tracking allows Federal Express to maintain positive control over shipments every step of the way. It is an integral a part of the system that FedEx promises to deliver all packages within one minute of the delivery commitment or the customer does not pay. The company also offers a second guarantee that is unique to the industry: if a customer cannot be told exactly where their package is, within 30 minutes of their inquiry, FedEx will pay the transportation costs of the package.

From COSMOS and tracking to service guarantees, the Federal Express network is designed to provide 100% customer satisfaction.

The Systems and Network Infrastructures

From managing internal efficiencies, FedEx saw the value of applying its systems and knowledge to improve customer service. FedEx understood the power of providing customers with real-time tracking and tracing ability as an integral part of transportation. As a result, customers are able to track the status of the shipment through Power Ship or FedEx Ship, the front-end applications that feed data about the packages to the backend COSMOS system. As more customer applications were developed, FedEx changed the definition of express transportation. The new definition means the aggregation of two main functions: the physical delivery of parcels and the management and utilization of the flow of information pertaining to the physical delivery (i.e., control over the movement of goods).

Today, FedEx markets its front-end services under the banner of "FedEx eShipping Tools". These stand-alone shipping tools consist of FedEx interNetShip® (a Web-based shipping application), FedEx Ship® (a shipping software package), FedEx Tracking (on-line tracking of packages through www.fedex.com), and Dropoff Locator (on-line viewing of 45,000 FedEx drop-off locations). In addition to these tools, FedEx also offers hardware-based tools, such as FedEx PowerShip® (a Dos-based shipping system that allows customers to interact with FedEx's extranet, download software and shipping information), FedEx PowerShipMC (a hardware/software system), FedEx DirectLink™ (for managing invoicing data electronically) and FedEx EDI

Electronic Invoice and Remittance (for integrating customers' own accounts payable application program with FedEx shipping transaction reporting). Today, FedEx PowerShip, FedEx Ship and FedEx interNetShip connects FedEx with more than two million customers. Figure 6.2.7 shows an example of how the PTT Post Group (The Netherlands) has integrated a Web-based shipping application that allows its customers to check the status of shipments through the postal company's Web page.

Postal Service Web Page
Customer browses the web page to check status of Express Shipment

Internet Network

Customer
Checks the status of shipments via the Postal Service Web Page

Customer PC

Note:
Rather than using a back process for checking status -- or using it in conjunction with the batch POD information, the Postal Service could use the FedEx Track WebAPI for dynamic tracking of shipments

FedExNet EDI Mailbox
The FedEx FedExNet system provides Shipping POD information to the customer -- for posting to the customer web site, thus allowing customers to check status of shipment

Internal Postal System
Typically Express shipments are registered on the internal system - this system can be used to create shipping transaction for FedEx shipping server

FedEx Shipping Server
This system is used to make FedEx shipments, shipping data can come from the customer system and be sent to the customer system

FedEx Transportation

Figure 6.2.7: PTT Post Group's Web Tracking Service

In addition to e-Shipping Tools, FedEx is also providing integrated solutions to address the entire selling and supply chains of its customers. Its "eCommerce Solutions" provide a full suite of services that allow businesses to integrate FedEx's transportation and information systems seamlessly into their own back-end operations. FedEx's strategy was in response to perceived changes in the market place. Businesses have been under pressure to expand their market reach while at the same time improving service quality. FedEx found the solutions to integrate the competitive advantage of its global transportation network and reliable express delivery into its customers' businesses. It markets four eCommerce Solutions: FedEx PowerShipMC (a multi-carrier hardware/software system), FedEx PowerShip® Server (a hardware/software system providing high-speed transactions, fully customized functions and superior reliability to businesses, allowing an average of eight transactions per second), FedEx ShipAPI™ (an Internet-based application that allows customization, eliminating redundant programming and saving time), and FedEx NetReturn® (an Internet-based returns management system).

The systems and technology infrastructure is now known as *FedExNet*. FedExNet enables business-to-business electronic commerce through combinations of global VPN connectivity, Internet connectivity, leased line connectivity and VAN connectivity.

6.2.2.3 Transforming FedEx into an e-Business

Building appropriate systems and technology infrastructure was the first step in transforming FedEx into an e-business. The next step, which overlapped the first in terms of timing, was the integration of business processes into these systems. This involved building expertise and credibility in logistics and supply chain management, improving seamless interconnectivity internally and externally with customers, and tapping into the growing e-tailing market to extend service offerings to consumers. Of greatest significance and value to customers and to FedEx is the transparency of processes because of integration.

The third step that FedEx took to transform its business was to undertake a major restructuring of its organization structure to align its organization structure with its systems and processes.

6.2.2.4 The Logistics and Supply Chain Management of FedEx

"FedEx is not only reorganizing its internal operations around a more flexible network computing architecture, but it's also pulling-in and in many cases locking-in customers with an unprecedented level of technological integration." By tracking back along the supply chain to the point of raw materials to identify points along the supply chain where it can provide management services, FedEx developed expertise in applying technology to shorten the order-to-delivery cycle. Often, these services include transportation; order processing and related distribution center operations, fulfillment, inventory control, purchasing, production and customer and sales services. The ability to interconnect and distribute information to all the players in a supply chain has become the focus of FedEx's attention. Figure 6.2.8 depicts some of the major program applications and products that FedEx has developed to address the various functions in the supply chain. In adopting these applications, many of FedEx's customers now view logistics as a key means for differentiating products or services from those of competitors.

National Semiconductor, for example, has formed an alliance with FedEx whereby FedEx acts as NatSemi's logistics department. Figure 6.2.9 shows the functions that FedEx performs on NatSemi's behalf from the point of receiving an order from a customer through to fulfillment. Throughout the supply chain process, NatSemi and its customer have immediate access to information regarding the status of the order, either through the NatSemi Website or through the FedEx Website.

As businesses place more emphasis on the order cycle as the basis for evaluating customer service levels, FedEx's role in providing integrated logistics systems forms the basis of many partnership arrangements. FedEx is managing warehouses and distribution systems for big manufacturers and even building entirely new electronic supply chain infrastructures for them.

By helping customers to redefine sources and procurement strategies so as to link in with other parties to the supply chain, FedEx customers are outsourcing supply chain management functions to FedEx. By improving, tightening and synchronizing the various parts to the supply chain, customers have seen the benefits of squeezing time and inventory out of the system. Tighter supply chain management is no longer viewed as a competitive advantage but a competitive imperative. Businesses searching for ways to improve their return on investment have become interested in any business process that could be integrated and automatically triggered (e.g., proof of delivery and payment) as opposed to being separately invoked. So not only is FedEx pushing its customers for integration, but its innovative customers are also demanding greater integration.

Some customers even went ahead of FedEx. Cisco, for example, developed an extranet that allowed its customers to order FedEx services without leaving the Cisco Website.

Stages of the Supply-Chain

FedEx Systems & Applications

The FedEx Integrated Logistics Solution

Supplier — Global Inventory Visibility System (GIVS)

Inbound (Purchasing) — GIVS / IMI / Warehouse Management System (WMS) / Transport Management System (TMS)

Manufacturing — Enterprise Resource Planning (ERP)

Order Management — ERP / IMI (Include invoicing)

Outbound (Transportation /delivery) — GIVS / IMI / *MultiShip* / Customs Clearance System

Figure 6.2.8: FedEx Solutions for the Entire Supply-Chain

Links have been established as FedEx has partnered with major third parties to integrate FedEx shipping and tracking capabilities into their software programs. To do so, FedEx has developed standardized file formats to enable the exchange of shipping, tracking and revenue data between third party systems and FedEx's systems. Some products have been developed for different platforms such as Windows or AS400, but utilize the PowerShip PassPort product to facilitate the exchange of data between the customer's system and the FedEx system.
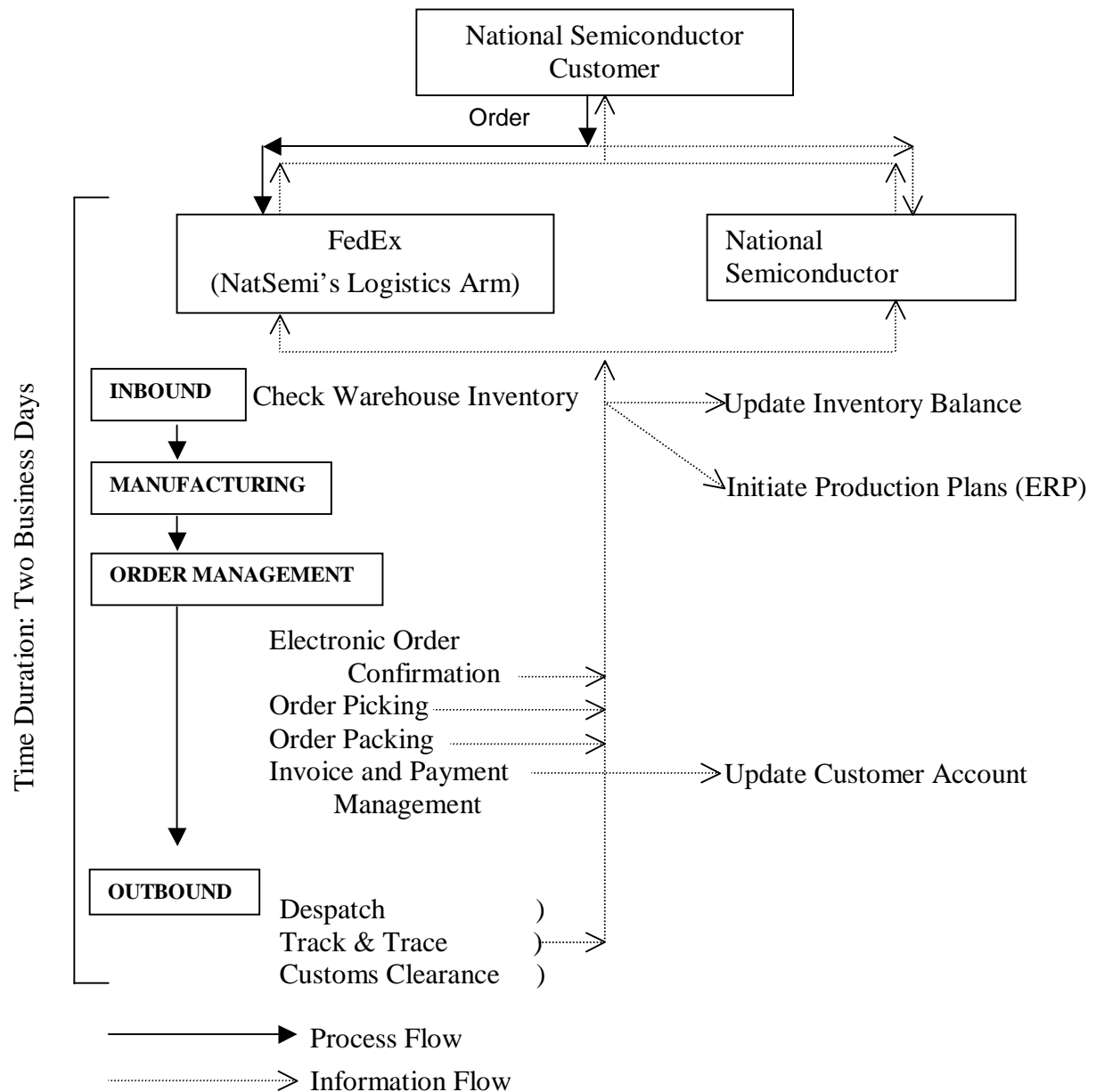
Figure 6.2.9 The Information Flow Value of Integrated Services to NatSemi's Customer

Compatibility of systems is ensured through complete understanding of the various software modules, developing specific business requirements, working closely with external vendors, extensive testing processes utilizing alpha, beta, soft roll-outs and utilizing out-sourced testing.

By integrating its services within the selling and supply chains of its customers, and thus generating increases in customer loyalty and in customers' switching costs, FedEx has managed to effectively raise the barriers to entry for competitors.

6.2.2.5 FedEx e-Commerce

Through experience, FedEx has developed a consulting capability to look at the internal processes of businesses and to identify where savings can be made on inventory. It has gained expertise in delivering workable supply chain logistics solutions to its customers by analyzing business processes and practices and coming up with a precise blend of transportation, logistics and information management that would improve productivity within the supply chain and boost profitability. Figure 6.2.10 gives one simple example of a FedEx eCommerce solution. It shows how customers can tap into a whole network of systems through the Internet. When a customer places an order through a Web catalog, the order is sent to the FedEx Web server. Information about the order and the customer is sent to the merchant's PC and a message is sent to the customer to confirm receipt of order. From that point up to the point of delivery of the goods, both merchant and customer may check the status of the order via the Web.
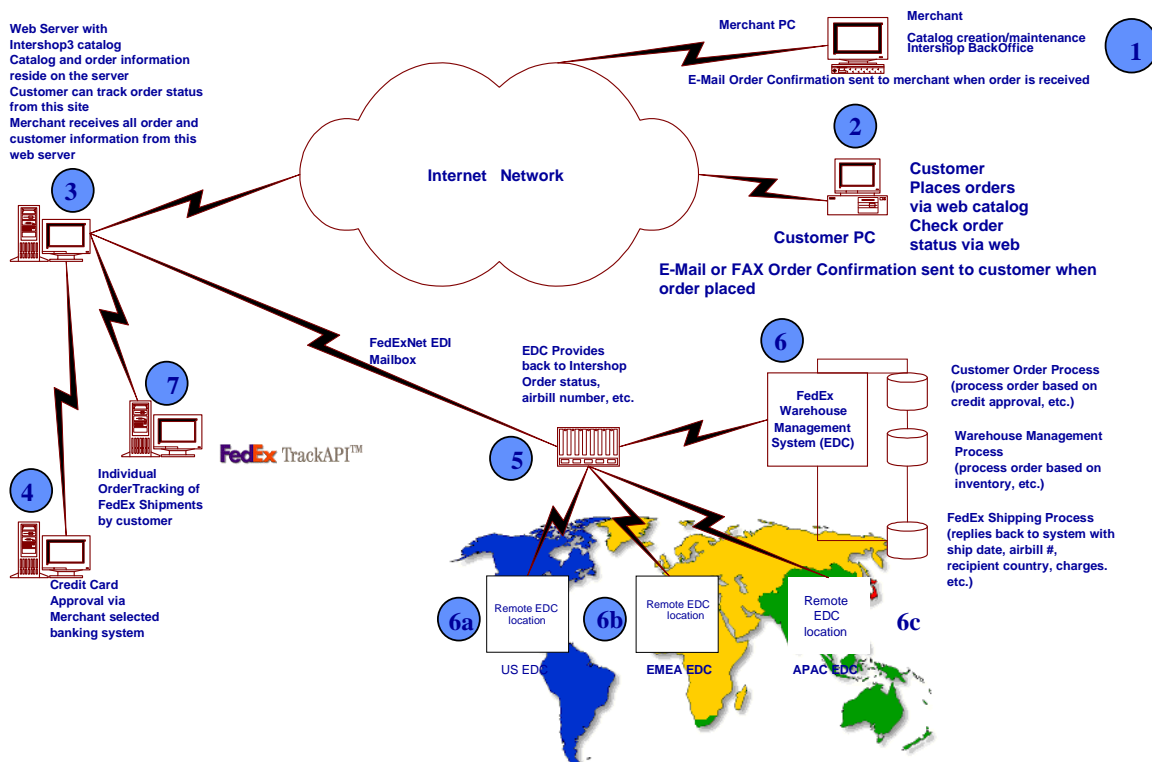
Figure 6.2.10 An Example of a FedEx e-Commerce Solution

The FedEx Web server then sends a message to the merchant's bank to obtain credit approval. At the same time, the order is sent via EDI to a FedEx mainframe that activates the warehouse management system. The order is processed (goods are picked, packed etc.), the warehouse inventory system is

updated, and the shipping process is synchronized. Information regarding the processing of the order is accessible at the three remote electronic data centers (EDC) located in the US, the Europe/Mediterranean (EMEA) and the Asia Pacific Regions (APAC).

For large established companies, this has entailed an aggressive overhaul of past practices and reengineering distribution functions. The small and medium-size companies generally tend to be pliant, while new startups are taking a new virtual approach, outsourcing from day one, their entire logistics and supply chain operations to third party logistics providers such as FedEx.

6.2.3 References

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6.2 Inventory and Warehouse Management through Wireless Communication

Implementation of cost-effective on-line, real-time information systems has been the objective of inventory and warehouse management since the advent of advanced computer and wireless technology. This section will focus on three aspects: (1) Wireless systems in warehouse inventory control. (2) Initiation of RFID technology in Boeing. (3) Application of RFID technology and Auto-ID Center in DOD. The material is extracted from some of the references cited.

6.3.1 Wireless Systems in Warehouse Inventory Control

In the area of warehouse inventory control, using Radio Frequency Data Communications (RFDC) technology is the one application that can most easily be cost- effective. It has been quoted that when RF technology is used in conjunction with real-time software and bar code, inventory accuracy of 99+% and error rates of less than 1% are achievable.

6.3.1.1. Radio Frequency (RF) system

RF systems integrate with the technologies of automatic identification systems (AIS), bar-coding, automatic data capture (ADC) and enhance electronic data interchange (EDI) and quick response (QR) systems. Together with other subsystems, manufacturing and distribution firms are better able to control inventory operations.

Today, managers of warehouse have greater needs (see Figure 6.3.1) toward improving their competitive position by reducing service costs, providing timely response to inquiries and delivering quality products in a timely manner. Procedures and equipment for providing automatic data collection (ADC) have been available for almost 40 years, progressing from punch cards to modern bar coding. To further the implementation of on-line, real-time systems, communication technology has integrated radio frequency data communications (RFDC) hardware and software systems into an ever-increasing number of company computer systems. Integrated together, the traditional logistical transactions are automatically processed and the visual displays provide paperless, timely and quality information necessary to maintain inventory control, customer satisfaction and profitable operations.
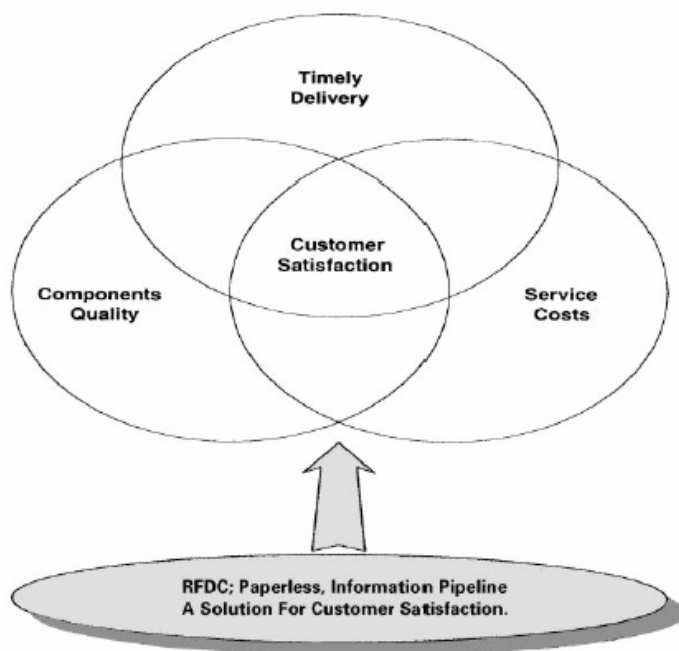
Figure 6.3.1: The objectives of ADC systems (Carlson, 1999)

6.3.1.2 Information flow with RFDC

With the support of RFDC, the logistical transaction information link (see Figure 6.3.2) between the information system (IS) of distribution center and the IS of customer or vendor can be on-line and real time. For the distribution center, this service is provided by an AWCS (automated warehouse control systems). This links with the IS of customers via the electronic data interchange (EDI). The AWCS can on-line real time update the transaction information with the RFDC terminals. These are hand-held or mounted on lift trucks. The laser bar code scanners on the terminals communicate directly with a host computer to monitor the real time transactions and verify the transaction.
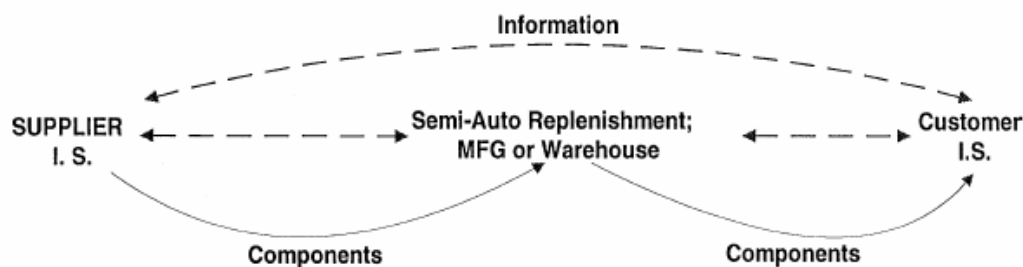
Figure 6.3.2: The external logistical information transmission (Carlson, 1999)

The transaction activities for this large Distribution Center start when the Purchasing department transmits a detailed component description of varieties, specifications, time and quantities of items to be acquired. When the order is ready for delivery, the Vendor sends an ASN through EDI to the warehouse, detailing the order deliver information regarding the transporter and planned arrival time. When the items arrive, the receiving personnel retrieve the ASN and direct the truck to the prearranged receiving dock. By bar code scanning, incoming items are identified and tracked. By computer-to-computer EDI, the data by the bar code scanning is automatically available for accounting, scheduling and inventory control. Internally, RFDC terminals and scanners operate on a unique frequency, transmitting its distinctive data stream in response to the bar code reader. The antenna transmits the signal to the warehouse communication system (WCS). A bar-coded label identifies an individual pallet and is used for tracking. By scanning the receiving documents, the part number, quantity, supplier and serial number are captured into a database of WCS by RFDC enabling the items to be tracked throughout its entire distribution system. The bar-coded pallet label, in conjunction with the computer record, contains all the data necessary to control the status and movement of the pallet through the system, see Figure 6.3.3. The lift truck driver scans the label on an incoming pallet and receives put-away instructions from the WCS. The instructions direct the movement to a specific rack location. The driver uses a hand-held scanner to scan the label on the pallet and the label on the rack and the WCS verifies that the transaction is correct. When retrieving the pallet for the picking operation, its number and location are given to the driver via the RFDC terminal. By scanning the bar code label on the pallet and the bar code on the rack position, if the transaction is correct, a confirmation signal is given and the driver delivers the pallet to the order filling area.
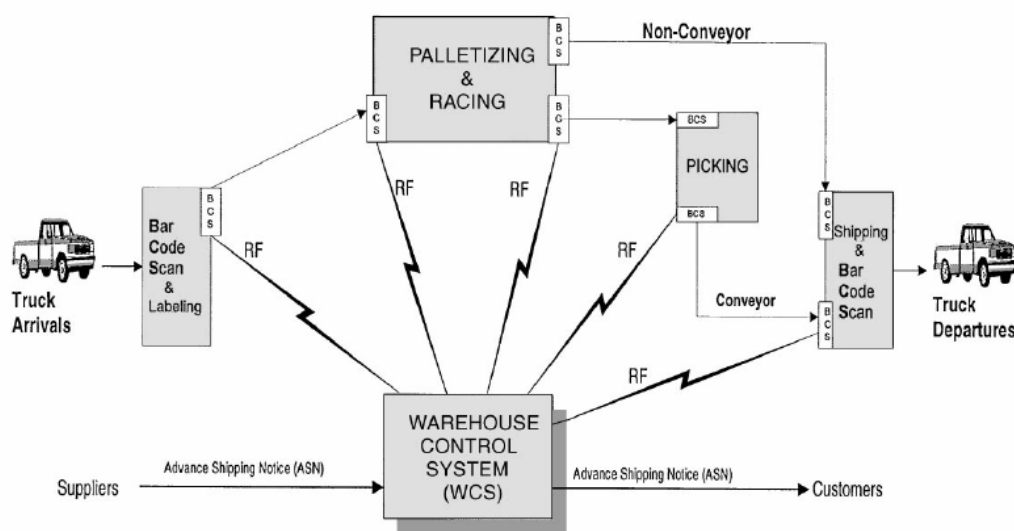
Figure 6.3.3: Typical logistical information flow with RFDC (Carlson, 1999)

The WCS identifies whether this load is conveyable or non-conveyable. Any non-conveyable items are moved directly to the shipping area. Pallets for conveyable items are moved to the order-picking area where individuals on the pallets are picked and placed on a conveyor. The individual cartons must have bar code labels attached in order that fixed beam scanners may read the bar code labels on the conveyor and transmit data to the RFDC to update the computer's database. The WCS controls the sortation function, diverts the carton to the proper shipping trunk for shipment to the customer. On the shipping dock, the load identification bar code is scanned, which automatically identifies and transmits the data about the contents of the load into the customer order file in the WCS. This information joins all related detail transaction information to make an ASN to the customer.

6.3.2 Initiation of RFID technology in Boeing

A new technology, known as RFID time temperature indicators (which efficiently monitor shelf life accurately), was introduced in Boeing. The time temperature indicators (TTIs) can improve the quality and freshness of perishable products. But TTIs haven't been widely adopted. A startup called Infratab is changing that by integrating TTIs with RFID tags. Most existing temperature sensors provide a visual indication that a temperature threshold has been reached. When the sensor is exposed to temperatures above a certain threshold, the label will appear a certain color. The color change is permanent, so the label provides a record of temperature exposure.

Infratab's tags are electronic. The tags have the same tracking capabilities as RFID systems but with additional capabilities of TTI. They consist of chip that senses temperature and integrates it over time to determine the shelf life of a product. The information can be communicated via RFID. The tags also have a battery and an optional visual display that provides green, yellow and red indicators of the status of the item.

There are several benefits using this technology: First, it can monitor the status of perishables in real time, while the traditional sensor can only used as static indicators. Infratab's tag can store information over time and recalculate the shelf life when temperature changes. It also retains the tracking capabilities of RFID systems. Second, the technology is cheaper than traditional data loggers, which store temperature information on a microchip. Third, this tag promises to be far more accurate than traditional "sell by/use by" dates. The RFID tags can be used in companies that need to monitor, in real time, the shelf life of perishable products - such as food, pharmaceuticals, chemicals or explosives - to ensure the product quality.

The price of the new tag depends heavily on what product it is monitoring. The TTI label requires a battery; hence the price is high when Boeing uses a large

size of battery. If the shelf life of the product is several years, then a more expensive battery is needed. The tags will likely cost around $1 for many products. The new technology will be well suited to supply chain management because it combines real-time monitoring of shelf life and RFID tracking. The first generation of RFID time temperature integrators follows the MIT Auto-ID Center to use its Class 3 and Class 4 Electronic Product Codes tags, while Class 0 and Class 1 EPC standards do not cover the data that Infratab's TTI integrated chips would need to deliver.

Although the RFID is an efficient technology for inventory and warehouse management, airlines have always been skeptical of any RF technologies to be used on planes. Because RFID allows airlines to store information and overwrite it as many times as necessary, also global RFID marking standard will benefit the entire worldwide airline industry and every supplier will be using the same marking standard. Boeing, the leading manufacturer of commercial aircraft, has set out to prove that RFID, 13.56 MHz, read/write tags which comply with ISO 15693 and offer one kilobyte of memory, poses no safety threats to air transportation.

There is lot of metal in a plane that could potentially interfere with the RFID technology. Boeing also wants to make sure everything it does is within the realm of open systems and architectures. As long as RFID works as well as Boeing expects, it could revolutionize how airlines mark and track parts for commercial aircraft.

6.3.3 Application of RFID technology and Auto-ID Center in DoD

6.3.3.1 Current Problems in the DoD Inventory Management

With such a large and complicated supply structure, there are bound to be problems and inefficiencies in the Department of Defense supply chain. Some of the major problems include inventory management where the DoD faces problems such as overstocking and delays in material shipping because supply is not available at a local retail or distribution depot. Repair and maintenance of large equipment is inefficient. Preventive maintenance is practiced leaving aircraft and other large machinery in the shop for longer periods of time. When a spare part is needed, an order is usually slow to come delaying repair even further. Finally, readiness and mobility is always an issue. The need to improve readiness in equipment and military supply is necessary to have a strong and fast fighting power. Supply efficiency is needed in order for soldiers to pack only what they need, thus improving mobility.

The previous logistics attitude of the military was to overstock everything, a "just in case" approach. This overstocking method came about for a number of reasons. Reorder formulas to determine reorder amounts have been developed and used throughout the years. One study found that workers often did not

understand the formulas and relied on past experience to determine reorder amounts. Improper record keeping of products received and ordered also proved to be a problem (Alexander, S.M. 1985). The most significant reason for overstocking however is the unreliability of order-and-ship time (OST). With a decreasing budget and more expensive technology, the military can no longer afford to merely overstock.

The longest process delays appear in the initial segment (order) and the final segment (transit, cross dock, and receipt processing). Delays in ordering are due to financial holds and manager reviews of individual requisitions. Delays also occur because managing what to stock, reorder points (ROP), and turn-over rates is very difficult due to the unpredictability and variability in demand and the use of highly varied products, from specialized, expensive, slow-to-order military equipment to common, fast, cheap civilian goods. A military customer usually gets 25% of supplies from local retail, 10% from neighboring retail, and 55% from wholesale. This procedure is extremely inefficient.

6.3.3.2 Existing RFID Technology in DoD

Radio frequency identification (RFID) technology is a growing strategy for improving supply chain efficiency in the Department of Defense. The Department of Defense has invested millions of dollars in the research and development of RFID systems to improve security, cargo visibility, inventory management, product tracking, and quality control.

6.3.3.3 The Auto-ID Center

The Auto-ID Center is an industry sponsored non-profit organization chartered to design the open standards-based system that connects all physical objects to the global Internet. This system is referred to as the Networked Physical World system. The five basic structures making up the Auto-ID Center 's system include (1) RFID tags and readers, (2) the Savant systems, (3) Electronic Product Code (EPC), (4) Object Name Service (ONS), and (5) Physical Markup Language (PML).

RFID tags

Electronic tags are the wireless connection between the physical and virtual world. Each tag consists of a small microchip that holds a unique identifier, an antenna that communicates with a reader, and an optional battery. Tags with batteries are "active" and have higher costs than a "passive" tag, with no battery, which harvests its energy from the reader to power the tag and communicate information. In addition to tags, the Auto-ID Center has developed a means to uniquely identify objects and a method of storing and retrieving data.

Savant System

A Savant system is an event router and local control system that performs operations such as data capture, data monitoring and filtering, and data

transmission. Networked Savant systems form a framework to manage and react to the EPC values communicated to the tag readers. The Savant systems are deployed in a hierarchical, distributed framework. This topology enables the Savant framework to handle large volumes of communicated EPCs from networked objects.

Electronic Product Code

The Electronic Product Code (EPC) is a globally unique identification scheme designed to uniquely identify all physical objects and aggregations of objects. The EPC code is sufficiently large to enumerate all objects. The EPC is intended, as much as possible, to be universally and globally accepted. Since the EPC is used primarily to link physical objects to the network, it was designed to serve as an efficient information reference. Finally, the code is extensible, allowing future expansion in both size and design.

The EPC representation consists of four distinct, hierarchical partitions: version number, domain manager number, class code, and serial number. All EPC coding contain these four partitions. The first partition, the version number, contains information on the length and structure of the code being used, and the three remaining partitions contain the actual unique identifier for the object.

Object Name Service

The Object Name Service (ONS) links the Electronic Product Code with its associated Physical Markup Language (PML) data file(s). The ONS is a system designed to automatically locate networked information and services for tagged objects. More specifically, the ONS is an automated networking service, which, when given an EPC number, returns a set of host addresses on which the corresponding PML files or services are located.

The ONS is based on the standard Domain Name Service (DNS). Within the ONS System, the EPC is translated into a valid DNS domain name. This domain name is used to obtain the set of IP addresses in the standard DNS manner. Unlike DNS, the ONS has multiple roots corresponding to a public and multiple private ONS hierarchies. The private ONS hierarchies are required to locate local information and services stored for a particular EPC.

Physical Markup Language (PML)

The Physical Markup Language (PML) is a language for describing physical objects. The PML is based on the eXtensible Markup Language (XML) and includes a set of schema describing common aspects of physical objects. The Physical Markup Language (PML) is intended to be a general, standard means for describing physical objects with particular emphasis on practical applications, such as inventory tracking, automatic transaction, supply chain management, machine control and object-to-object communication.

Inventory Management Across the Board

The DoD has been testing RFID technology for a number of years but the key element that they are missing in their implementation is the advantage of standardization. Everything in the world will be uniquely identified under the same standard system in the Auto-ID Center's vision. With a standard system, DoD can become a more integrated system within itself and in conjunction with the civilian world.

A standard system of automatic identification across the entire DoD will facilitate inventory management; thereby creating increased readiness at a reduced cost.

As discussed in 6.3.3.1, a major issue in inventory management is reorder amount. The Auto-ID system provides a method of real-time automatic inventory tracking. In the case of reordering MREs (Meals, Ready, Eat) for a battalion, a commander need only read the number of available MREs off a computer screen to know how much should be reordered. In a more advanced military, the reorder is performed automatically.

Distribution of goods can become more efficient when there is a single database of inventory movement. A military customer usually obtains 25% of supplies from local retail, 10% from neighboring retail, and 55% from wholesale as discussed in 6.3.3.1. With a standardized system, the DLA has more visibility of reorder patterns (customer demand) and inventory movement amongst distribution centers and between distribution centers and supply points. Efficiency in supply will improve.

RFID technology coupled with mass serialization and the ONS database allows for real-time tracking of supplies from a single source. In the case of maintenance and spare parts, a standardized system of inventory management will give visibility to where spare parts are located. Maintenance and repair becomes more efficient.

6.3.4 References

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[2] Kenneth.D.Porad, Boeing And Airbus Initiate RFID "Pilot" Program, 2003.

[3] Elaine M. Lai, An Analysis of the Department of Defense Supply Chain: Potential Applications of the Auto-ID Center Technology to Improve Effectiveness, May 2003.

[4] AURORA bar code technologies, AIDC (Automated Identification and Data Collection) Technical & Informational Documents.

[5] Boeing Company, Boeing Center for Technology, Information and Manufacturing Technology Round up, August 2003.

6.4 OA Tables

6.4.1 Non-Stocked Item

Typical customer (defined as using unit) identifies a need for a product that must be fulfilled by the logistics chain (Garrison or Deployed). Product is not on hand at the (Intermediate Supply Agency) ISA.

	Speaker	Listener	Performative	Content Description	Attributes/ Media	Comments
Same with Step 1.1 to 10.0 in Stocked Item Case						
1.1	ICM	PCM	Inform	Signal PCM about the requirements		
1.2	PCM	PPM	Ask / Accept	PCM asks PPM to reserve the products and make available for distribution.	NSNs, Quantity, Order ID - **Text, Voice**	The specific list of consignments is sent so as to enable the PPM to reserve these products.
1.3	PPM	PE	Request - Commit	PPM requests to source and reserve the items.	NSNs, quantity, packing rqmts, Time to pick-up, Priority - **Text, Voice, Digital**	The work order that contains the consignments to be made ready for delivery can be sent as an e-form. The priority is a machine generated digital code.
1.4.1	PE	PPM	Inform	PE signals the capability to PPM	Signal **- Digital, Text**	The availability of the products are confirmed by a digital code or using a text form.
1.4.2	PPM	PCM	Inform	PPM signals PCM about the availability of the products once signal is received from PE.	Signal - **Digital, Text**	The signal received from PE if routed to PCM.
1.4.3	PCM	ICM	Inform	PCM signals to ICM that the items will be made available. The items are placed as back-orders.		

1.4.4	ICM	OM	Commit	Informs OM that the items are available to promise	Order ID, Confirmation - **Text, Voice**	The order id is reiterated to the OM and the products are confirmed as available to promise.
2.0	ICM	DCM	Inform	Signals the shipping requirements		
3.1	DCM/ICM	ICM/DCM	Ask / Accept	Co-ordination for Pick-up for delivery.		
3.2	ICM	OM	Inform	ICM signals OM, so as to enable OM to manage the fulfillment issues.	Order ID, Packaging info, time to pick up. - **Text, Voice**	
3.3	IPM	IE	Request/Commit	IPM orders IE for the receiving the delivery from the external source.	Order ID, Consignment Labels, Time to delivery -**Text, Voice, Image**	The Labels of the consignment are sent using image files while the list and time information can be sent using Text forms.
4.1	IE	IPM	Inform	Notifies IPM upon receiving the orders from the external source	Receipt - **Text, Voice**	The receipt generated upon receiving the order will be in text form, a verbal confirmation may be used to supplement the communication.
4.2	IPM	ICM	Inform	Signals ICM about the receipt of the orders	Receipt - **Text, Voice**	The receipt is routed to ICM node.
4.3	ICM	OM	Inform	Signals OM about the orders received.	Signal - **Text, Voice**	Sends a confirmation of receipt.
4.4	OM	FM	Inform	Notifies FM that the products were received from the external source and a receipt is sent.	Invoice - **Text, Encryption**	The financial invoice for transfer of funds is sent as text but needs to be encrypted.
Same with Step 15.0 to 20.0 in Stocked Item Case						

6.4.2 Multiple Source Item

Typical customer (defined as using unit) identifies a need for multiple products that must be fulfilled by the logistics chain (Garrison or Deployed). Products are cataloged items, acquired from multiple sources, and delivered as a completed layette. Internal items are not sourced from multiple organic warehouses, but some items are sourced from the same warehouse where the layette is being built.

Step	Speaker	Listener	Performative	Content Description	Attributes/ Media	Descriptions
Same with Step 1.1 to 3.0 in Stocked Item Case						
1	ICM	PCM	Ask	Check ability/availability to acquire products		
Same with Step 4.0 to 10.0 in Stocked Item Case						
2.1	ICM	PCM	Inform	Source external items		
2.2	ICM	OM	Inform	Informs NS2.1 to OM		
Same with Step 11.0 to 14.0 in Stocked Item Case						
3.1	IE	IPM	Inform	Informs 21.1		
3.2	IPM	ICM	Inform	Informs 21.1		
3.3	ICM	OM	Inform	Informs 21.1		
4.0	OM	FM	Inform	Signals of receipt verification of external items.		
Same with Step 15.0 to 20.0 in Stocked Item Case						

6.4.3 PROCUREMENT FULFILLMENT

Appropriate capacity management (xCM) identifies or receives a need for a product/service that must be fulfilled by the logistics chain (Garrison or Deployed) that must be sourced externally.

Step	Speaker	Listener	Performative	Content Description	Attributes/ Media	Descriptions
1.0	xCM	PCM	Request	Submit the order	Unit Identification, NSNs Quantity, Location, Expected time for replenishment. - **Text, Digital, Voice**	The order could be sent as an e-form. The location information is identified by the GPS enabled device and sent along with the form. The voice acts as a backup for human – human.
2.0	PCM	PPM	Ask	Reserve and Schedule	NSNs, Quantity, Order ID, Time frame. - **Text, Voice**	The list and quantity of items and time frame can be sent using text forms.
3.0	PPM	PE	Inform	Route the order for the fulfillments	2.0 + Location info, route - **Text voice Digital**	The location information is obtained from the GPS and is sent as a digital code.
4.0	PE	Provider/ Supplier	Ask	Check availability and capability	Confirmation - **Text, Voice**	
5.0	PE	Provider/ Supplier	Ask	Negotiates to deliver products/services within the customer's requirement.	Negotiation - **Voice**	
6.1	PE	Provider/ Supplier	Request	Release the order		
6.2	PE	PPM	Inform	Inform the order releasing.		
6.3	PPM	PCM	Inform	Inform the order releasing.		

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7.1	PCM	PPM	Inform	Notify or receipt verification and provider payment. Finally to PE.		
7.2	PPM	PE	Inform	Inform 7.1. (PE is actual listener)		
8.0	PE	PPM	Inform	Inform that sourcing order is closed.		

6.4.4 References:

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[2] Kumara S.R.T., Dodd. C, and Kim. T, "Web-based Distributed Multi-agent Architecture for implementing Value Nets", in Prabhu, V., Kumara, S.R.T., and Kamath, M., (co-editors), Scalable Enterprise Systems, pp. 313-333, Kluwer's Academic Publishers, 2003.

[3] MCRU-PSU Team, "Enabling Logistics with Portable and Wireless Technology Study" Interim Report #1 dated 8th September 2003.

6.5 Technical specifications of Wireless technologies

Technology Description

6.5.1 Short range Wireless Communications

Short-range wireless refers to a group of technologies that enable wireless data networking across distances between one and a few hundred meters. In recent years, the short-range wireless marketplace has expanded to a wide base of technologies and standards supporting a diverse range of requirements. This section concentrates on describing these technologies.

6.5.1.1 Bluetooth

Bluetooth technology creates a short-range wireless (ad-hoc network) voice and data link between a broad range of devices such as PCs, notebook computers, handhelds and PDAs, Smart Phones, mobile phones and digital cameras. Bluetooth technology is based on a short-range radio link built into small application-specific integrated circuits (ASICs).

6.5.1.1.1 Specifications & services

6.5.1.1.1.1 IEEE 802.15.1, WPAN (Wireless Personal Area Network) solution
6.5.1.1.1.2 Short-range wireless voice and data link (Full duplex; typical distance: ***10 meters***)
6.5.1.1.1.3 Frequency band of operation: 2.4 GHz (2.402 GHz to 2.480 GHz)
6.5.1.1.1.4 Modulation scheme: Gaussian BFSK [BT = 0.5]
6.5.1.1.1.5 Multiple access scheme: FHSS (hops to 79 defined frequencies separated by 1 MHz; hopping frequency -1600/seconds)
6.5.1.1.1.6 Data rates: ***723.2 Kbps*** (1 Mbps including error correction bits)
6.5.1.1.1.7 5-layer protocol architecture implemented in software and hardware
6.5.1.1.1.8 A maximum of 8 nodes (1 master with 7 slaves results in seven simultaneous connections) in a network. A maximum of 255 passive slaves supported in a network. A single such network is known as Piconet. All active nodes hop simultaneously, with master dictating the hop sequence.
6.5.1.1.1.9 Master to slave link can be point-to-point or point-to-multipoint
6.5.1.1.1.10 Initial set-up/ session establishment with the access point is required
6.5.1.1.1.11 Three classes of Bluetooth devices categorized on the basis of transmitted power
Class 1 (Maximum O/p power: 100mW [20 dBm] with range of 100 meters)
Class 2 (Maximum O/p power: 2.5mW with range of 10 meters)
Class 3 (Maximum O/p power: 1mW [1 dBm] with range of 1 meter)
6.5.1.1.1.12 Small form factor, low power consumption
6.5.1.1.1.13 Consumes more power than IR communication devices but less than 802.11 devices

6.5.1.1.1.14 Security is ensured in three ways:
- Challenge-response routine for authentication - prevents spoofing and unwanted access to critical data and functions.
- Stream cipher for encryption - prevents eavesdropping and maintains link privacy.
- Session key generation - session keys can be changed at any time during a connection

6.5.1.1.1.15 Interference with 802.11 technology devices but since Bluetooth devices hops far faster then 802.11 devices; transmission in 802.11 devices get more affected than among Bluetooth.

6.5.1.1.1.16 No LOS communications required

6.5.1.1.1.17 Cost: Between 5$ and 10 $

6.5.1.1.1.18 Supported connections

Synchronous Connection Oriented (SCO) for real time data and voice communications. 3 simultaneous voice call (each 64 Kbps, full duplex) are supported in a single Piconet. Asynchronous Connection Less (standard data) – Packet switched, deliver on best effort basis.

Two modes are supported:
- Asymmetric: 723.2 Kbps in one direction and 57.6 in other direction
- Symmetric: 433.9 Kbps in both directions

6.5.1.1.1.19 Supports TCP/IP and OBEX protocol on top of physical layer for data communications

6.5.1.2 Wi-fi / IEEE 802.11

IEEE 802.11 is a standard used for wireless computer communications. Today it is widely found in laptops, corporate workstations and home computers. This standard allows for wireless networking at a distance of up to 100 meters. 802.11 functions very much like a hub with Ethernet ports. An Access Point plays the part of the hub and a transceiver in the client acts as the end node, like an Ethernet card on a wired network.

To date, IEEE has developed three specifications in the wireless LAN 802.11 family: 802.11a, 802.11b and 802.11g. All three of these specifications use Carrier Sense Multiple Access with Collision Detection (CSMA/CD), as the path sharing protocol. If a source station has a data packet to send, the station checks the system to see if the path medium is not busy. If the packet medium is not busy, the packet is sent; otherwise the station waits until the first moment that the medium becomes clear.

Other differences and advantages of each over other are described below. The standard most widely used today, is IEEE 802.11b. These standards provide a mechanism to encrypt all traffic from the access point to the card. Moreover, this mechanism also allows a card to authenticate to the access point. Authentication

is needed because a user might be out of range and later come back into the range of transmission area.

6.5.1.2.1 IEEE 802.11a specifications & services

6.5.1.2.1.1 WLAN (Wireless Local Area Network) solution

6.5.1.2.1.2 Frequency band of operation: 5 GHz (U-NII band) Total 300 MHz in 3 bands. These are:

- 5.15 GHz to 5.25 GHz (4 channels) [Max power < 50 mW]
- 5.25 GHz to 5.35 GHz (4 channels) [Max power < 250 mW]
- 5.725 GHz to 5.850 GHz (4 channels) [Max power < 1 W]

6.5.1.2.1.3 12 channels, Center frequencies are 20 MHz apart

6.5.1.2.1.4 Data rates: 54Mbps maximum

6.5.1.2.1.5 Coverage: 54 - 60 ft (16 – 18 meters)

6.5.1.2.1.6 Spectrum spreading: OFDM (Orthogonal Frequency Division Multiplexing)

6.5.1.2.1.7 Modulations: BPSK, QPSK, 16-QAM

6.5.1.2.1.8 Less susceptible to interference in comparison to 2.4GHz band technologies

6.5.1.2.1.9 Does not interoperate with 802.11b devices

6.5.1.2.1.10 More access points are required in the network in comparison to 802.11b devices (typical ratio is 16:1)

6.5.1.2.1.11 More suitable in open office environments in view of the signal penetration characteristics at higher frequencies

6.5.1.2.1.12 A good solution if the end users are densely populated as it can accommodate more users per access point

6.5.1.2.1.13 Good for bandwidth hungry applications such as video conferencing

6.5.1.2.1.14 Comparing the performance with 802.11b in LOS and non-LOS environments, 802.11a offers an average path loss difference is 7 dB in LOS environments and of 2-3 dB in non-LOS environments.

6.5.1.2.1.15 Expensive in comparison to 802.11b devices

6.5.1.2.1.16 Depending upon the distance from the access point and network load, 802.11a device scale data rates between 6Mbps – 54Mbps

6.5.1.2.1.17 Knowledge of the network set-up is required for connection establishment

6.5.1.2.2 IEEE 802.11b Specifications & Services

6.5.1.2.2.1 WLAN (Wireless Local Area Network) solution

6.5.1.2.2.2 Frequency band of operation: 2.4 GHz (2.400 GHz to 2.483 GHz). Total available band: 83 MHz

6.5.1.2.2.3 14 channels, 5MHz apart

6.5.1.2.2.4 Bandwidth: 11Mbps

6.5.1.2.2.5 Coverage: 300 ft (90 meters)

6.5.1.2.2.6 Susceptible to interference as most of the short range wireless networks operate in this frequency band

6.5.1.2.2.7 Modulation schemes: BPSK, QPSK

6.5.1.2.2.8 802.11b uses DSSS (Direct Sequence Spread Spectrum) to disperse the data signal over a relatively wide (30MHz) portion of 2.4GHz band (which increases the communication channels interference immunity or the processing gain, decreases interference between multiple users and increases the ability to re-use the spectrum)

6.5.1.2.2.9 Radio adapts – (trade off between power and slower data rate with distance)

6.5.1.2.2.10 Secured using WEP (Wired Equivalent Privacy) key (64 bits/ 128 bits)

6.5.1.2.2.11 MAC filtering allows barring of specific MAC addresses

6.5.1.2.2.12 Does not interoperate with 802.11a devices since two operate on different frequencies

6.5.1.2.2.13 Knowledge of the network set-up is required for connection establishment

6.5.1.2.3 IEEE 802.11g Specifications & Services

6.5.1.2.3.1 WLAN (Wireless Local Area Network) solution

6.5.1.2.3.2 Frequency band of operation: 2.4 GHz (2.400 GHz to 2.483 GHz).

6.5.1.2.3.3 Bandwidth: 11 - 54Mbps

6.5.1.2.3.4 Variable range: 20 - 90 meters (less at higher bandwidths)

6.5.1.2.3.5 Multiple access scheme (Spectrum spreading): DHSS & OFDM

6.5.1.2.3.6 Better handling of signal reflection than 802.11b as it slices ups the spectrum in a way that enables receivers to handle these reflections in a simpler and effective way.

6.5.1.2.3.7 Backward compatibility and interoperability with 802.11a and 802.11b devices

Additional notes on IEEE 802.11 standards
- 802.11 device support conventional TCP/IP protocol suite on top of MAC and physical layers
- 802.11 device support voice using VoIP protocol suite
- 802.11 devices do not yet have complete telephone functionality. Features like caller ID are not available
- Since 802.11 depends on a distributed contention based algorithm, it induces latency in voice transmissions

Table 6.5.1: 802.11 Technologies Comparison

802.11 Technologies Comparison			
	802.11a	802.11b	802.11g
Max data rate	54 Mbps	11 Mbps	54 Mbps
Maximum range (meters)	18	90	20-90
Supported Data Rates	6, 9, 12, 18, 24, 36, 48, 54 Mbps	1, 2, 5.5, 11 Mbps	OFDM: 6, 9, 12, 18, 24, 36, 48, 54 Mbps CCK: 1, 2, 5.5, 11
Frequencies	5.15–5.25 GHz 5.25–5.35 GHz 5.725–5.875 GHz	2.4–2.483 GHz	2.4–2.483 GHz

- Use of OFDM over DSSS provides higher data rates and improves transmission echo and distortions resulting from multi path propagation and radio frequency interference
- HIPERLAN1 and HIPERLAN2 are known names for equivalent technologies adopted by ETSI in Europe.

6.5.1.3 IEEE 802.15.4

IEEE 802.15.4 provides for *low-data-rate* connectivity among relatively simple devices that consume *minimal power* and typically connect at distances of 10 meters (30 feet) or less. Potential applications are sensors, interactive toys, smart badges, remote controls, and home automation.

IEEE 802.15.4 is a MAC and physical layer specification. ZigBee and LAMP (Link Adaptation and Management Protocol) are two protocol suites that sit on top on MAC to provide the above-mentioned applications.

6.5.1.3.1 Specifications & services

6.5.1.3.1.1 WPAN (Wireless Personal Area Network) solution
6.5.1.3.1.2 Frequency bands:
- 858 MHz [No of channels: 1; Data rate: 20 Kbps]
- 902-928 MHz [No of channels: 10; Data rate: 40 Kbps]
- 2.4 GHz [No of channels: 16; Data rate: 250 Kbps]
6.5.1.3.1.3 Data rates: 10 – 250 Kbps, duplex
6.5.1.3.1.4 Modulation: MSK or BPSK (depending on the date rate)
6.5.1.3.1.5 Range: 10 meters or less
6.5.1.3.1.6 Multi-month and multi-year battery life
6.5.1.3.1.7 Security implemented using CCM integrity/encryption
6.5.1.3.1.8 Reliable data delivery
6.5.1.3.1.9 Very low complexity
6.5.1.3.1.10 No LOS requirements

6.5.1.4 HomeRF

The HomeRF Shared Wireless Access Protocol (SWAP) is designed to carry voice and data within the home. It can operate either as an ad-hoc peer to peer network that provides traditional data networking or as a managed network under the control of a connection point.

HomeRF is implemented in the Physical and MAC layers. Beyond MAC, it makes use of the existing PC industry infrastructure of the Internet, TCP-IP and DECT. Standard are also available in HomeRF, which offers a way to connect to the PSTN for voice telephony. Future specifications of SWAP are currently being researched and developed. It is envisaged that these future specifications will offer increased security and higher data rates.

HomeRF is being developed by ITU.

6.5.1.4.1 Specifications & services

6.5.1.4.1.1 Frequency band of operation: 2.4 GHz
6.5.1.4.1.2 Bandwidth: 10Mbps
6.5.1.4.1.3 Range: 150 ft (45 meters)
6.5.1.4.1.4 Modulation: FSK (2FSK for 1Mbps and 4FSK for 2Mbps)
6.5.1.4.1.5 Security using frequency hopping (50 hops per second) and encryption key
6.5.1.4.1.6 Multiple access schemes:
  - TDMA to support the delivery of isochronous data
  - CSMA/CA service is provided to support the delivery of asynchronous data.
6.5.1.4.1.7 Network is capable of supporting 127 nodes
6.5.1.4.1.8 Transmission power: 100 mW
6.5.1.4.1.9 Voice communication support based on DECT (Digital Enhanced Cordless Telephony). Support 4 high quality voice connections simultaneously.
6.5.1.4.1.10 Voice connections: Up to 6 full duplex conversations
6.5.1.4.1.11 Data Security is implemented using a 24-bit network IP that is specific to each personal area network. Along with that, data is sent using a 56-bit encryption algorithm. This algorithm is powerful than A5 algorithm used in GSM.
6.5.1.4.1.12 Data Compression: LZRW3-A algorithm
6.5.1.4.1.13 24 bit unique Network ID for each personal area network
6.5.1.4.1.14 Cost of implementation is higher than IrDA

6.5.1.5 IrDA

Infrared Data Association is an industry standard for infrared wireless communication. Infrared systems transmit data between devices using infrared light. The light source can be a Light Emitting Diode (LED) or an Injection Laser Diode (ILD). Photodiodes are required to receive the signals.

IrDA includes a set of specifications for physical and link layer. The link layer protocols are IrLAP (Link Access Protocol) and IrLMP (Link Management Protocol and Information Access Service (IAS)). IrDA compliant infrared transceiver, which enables communication between devices such as printers, modems, fax, LAN, laptops, cordless telephones and other peripherals are commonly used.

6.5.1.5.1 Specifications & services

6.5.1.5.1.1 Frequency band of operation: THz (1,000GHz)

6.5.1.5.1.2 Data rates: Variable depending upon the power used. (Maximum: 16 Mbps)

6.5.1.5.1.3 Range: Maximum 2 meters

6.5.1.5.1.4 Supports bidirectional communications

6.5.1.5.1.5 Allows only point-to-point connections ensuring ordered data delivery

6.5.1.5.1.6 **Power consumption is very low, resulting in a very long battery life**

6.5.1.5.1.7 Data packets are protected using CRC-16 (for 115 Kbps) & CRC-32 (4 Mbps)

6.5.1.5.1.8 **Requires *LOS* (line of sight) communications**

6.5.1.5.1.9 Supports only data transmission (voice support through IP)

6.5.1.5.1.10 Low cost solution (2$ or so)

6.5.1.5.1.11 No initial configuration is required for session establishment. "Plug-n-play" – "Point-n-shoot" type devices. IrLAP layer implemented in the protocol suite automatically performs device discovery.

6.5.1.5.1.12 Application support: TCP/IP & OBEX

6.5.1.6 Ultra Wide Band Radio

Ultra-Wideband (UWB) technology transmits digital data at very high rates using very low power. In addition, UWB has other useful characteristics such as low fading, the ability to carry signals through obstacles and low cost implementation. These characteristics give this technology the potential to be utilized for high speed, short-range indoor wireless transmission.

UWB occupies a bandwidth of more than 25% of a center frequency, or more than 1.5GHz. This bandwidth is much greater than the bandwidth used by any current technology for communication. Secondly, UWB is typically implemented in a carrier-less fashion. Conventional narrowband and wideband systems use Radio Frequency (RF) carriers to translate the signal in the frequency domain from base-band to the actual carrier frequency where the system is allowed to

operate. Conversely, UWB implementations directly modulate an impulse that has a very sharp rise and fall time, thus resulting in a waveform that occupies several GHz of bandwidth. Essentially, it uses radio impulses to transmit information. The availability of very wide bandwidth allows the use of low power to communicate information without seriously degrading the performance of other narrowband users in the same frequency range.

Presently, task group is discussing two proposals. These are:
OFDM-based multi-band approach
Dual band impulse radio spread spectrum approach
Drafting of the standards is likely to be completed by November 2003

The high data rates afforded by UWB systems will tend to favor applications such as video distribution and/or video teleconferencing for which Quality of Service (QoS) will be very important.

6.5.1.6.1 Specifications & services

6.5.1.6.1.1 EEE 802.15.3a, WPAN (Wireless Personal Area Network) solution
6.5.1.6.1.2 Operates in 3.1 GHz to 10.6 GHz frequency band
6.5.1.6.1.3 Data rates: 110 – 480 Mbps
6.5.1.6.1.4 Range: less than 10 meters [110 Mbps for 10 meters; 220 Mbps for 4meters; 480 Mbps for 2 meters]
6.5.1.6.1.5 EIRP: - 41.3 dBm
6.5.1.6.1.6 Power consumption: 100 mW and 250 mW
6.5.1.6.1.7 UWB Radio is a physical layer standard technology. It operates with MAC defined by IEEE 802.15.3 task group.
6.5.1.6.1.8 Characteristics of OFDM based multi-band approach
  - Three 528 MHz channels in Group-A (3.168 – 4.752 GHz band). Ten optional bands in Group B (4.752 – 6.072 GHz), Group C (6.072 – 6.184 GHz) & Group D (8.184 – 10.296 GHz)
  - Modulation schemes: TFI-OFDM (128-point FFT) and QPSK
  - Multiple access scheme: TDMA/ FDMA
  - Error correction: Convolutional coding [11/32 @ 110 Mbps, 5/8 @ 200 Mbps, 3/4 @ 480 Mbps]
  - Link Margin: 5.3 dB for 10m; 10.0 dB for 4m; 11.5 dB for 2 m
  - Symbol period: 312.5 ns OFDM symbol
  - Does not require an equalizer at receiver
  - Better resistance of ISI in comparison to dual band impulse radio spread spectrum approach
  - Better flexibility in co-existing with other wireless systems operating in the same frequency bands and also in case the whole band of 3.1 GHz to 10.6 GHz cannot be used
6.5.1.6.1.9 Characteristics of dual band impulse radio spread spectrum approach
  - 2 bands (3.2 – 5.15 GHz, 5.825 – 10.6 GHz)
  - Bandwidth: 1.368 GHz & 2.736 GHz

- Modulation schemes: BPSK, QPSK, DSSS
- Multiple access scheme: Ternary CDMA
- Error correction:
  - Convolutional coding: 1/2 @ 110 Mbps
  - Reed-Solomon coding: (255,223) @ 200 Mbps & 480 Mbps
- Link Margin: 6.7 dB for 10m; 11.9 dB for 4m; 1.7 dB for 2 m
- Chip time: 731ps (Low band) & 365.5ps (High band)
- Require a RAKE equalizer at receiver
- Better technology if the entire band of 3.1 GHz to 10.6 GHz is used

6.5.1.6.1.10 Highly secured data transmission intended
6.5.1.6.1.11 Supported applications include
- Video conferencing
- Wireless video and audio distribution systems
- New home entertainment appliances
- Diskless computers
- Position location and navigation applications

6.5.1.7 VHF/ UHF communications

VHF/UHF Communications System is used to transmit and receive both voice and data in the VHF range (30 - 300 MHz) and the UHF range (300 MHz - 3 GHz). It is used for communications systems, which require the transmission of large bandwidths over short distances (generally line-of-sight). Small, directional antennas are economical and effective. The UHF band is used for fixed communications services, ground-to-air communications, mobile services, and television. Other non-communications services include: radar, space research, radio astronomy, and telemetry.

6.5.2 Satellite Communications

The field of communications has been revolutionized by the development of satellite communication systems, which provide connectivity to a user on a global basis. This type of connectivity is known as Global Mobile Personal Communications by Satellite (GMPCS). Cellular communications provide connectivity mostly on land but fail to provide coverage in mountains, deserts and other tough terrain environments. However, GMPCS do not suffer from such limitations.

Currently, the services as well as the cost of the handsets are comparatively unaffordable and that's leading to financial problems in handling the operation of the systems. Satellite communications providers are trying to circumvent this problem by entering into roaming agreements with local cellular service providers. This enables the users to get services from the latter's networks, wherever available, and use the satellite services otherwise.

6.5.2.1 Iridium

The Iridium Satellite System provides a global, mobile satellite voice and data solutions with complete coverage of the Earth (including oceans, airways and Polar Regions). Through a constellation of 66 low-earth orbiting (LEO) satellites operated by Boeing, Iridium delivers essential communications services to and from remote areas where terrestrial communications are not available. The service is ideally suited for industrial applications such as heavy construction, defense/military, emergency services, maritime, mining, forestry, oil and gas and aviation.

Iridium currently provides services to the United States Department of Defense and launched commercial service in March 2001.

6.5.2.1.1 Specifications

6.5.2.1.1.1 66 satellites in LEO (Altitude: 780 km or 485 miles)
6.5.2.1.1.2 6 Orbital planes (Orbital period: 100 min, 28 seconds)
6.5.2.1.1.3 Bands of operation
- 1616 -1626.5 MHz (L-Band) ← → Satellite – handset transmission
- 23.18 – 23.38 GHz (Ka-Band) ← → Inter-satellite communications
- 19.4 -19.6 GHz (Ka-Band) ← → Ground Segment (Downlink)
- 29.1 – 29.3 GHz (Ka-Band) ← → Ground Segment (Uplink)

6.5.2.1.1.4 Multiple Access Schemes – FDMA/ TDMA
6.5.2.1.1.5 Coverage of Iridium could be seen as the whole surface of the Earth divided into 1628 cell, with each satellite covering a maximum of 48 cells (by way of beams).
6.5.2.1.1.6 Each satellite has a capacity of 3840 channels. Some are used for paging and navigation, while others are used for data and voice.
6.5.2.1.1.7 Iridium satellites do have switching fabric, meaning that calls between distant customers are routed through a matrix of satellites in space itself.
6.5.2.1.1.8 Link Margin – 16 decibels (average)
6.5.2.1.1.9 Motorola Series 9505 handsets cost about $1500 with an additional cost of $400 for handling data calls
6.5.2.1.1.10 A variety of subscriber equipment is available to communicate with the Iridium network, including dual-mode handsets, specialized aeronautical and marine units, numeric and alphanumeric pagers.

6.5.2.1.2 Services

6.5.2.1.2.1 Voice services
- Supplementary services (Call forwarding)
- Voice mail boxes

6.5.2.1.2.2 Data services
Dial-ups
- Supported data speed – 2.4 Kbps

Direct Internet Data

- Supported data speed – 10 Kbps
- Compression algorithms are implemented
- Seamless connection and disconnection, when no transmission

6.5.2.1.2.3 SMS
- 160 alphanumeric characters
- Support SMS sending to e-mail addresses

6.5.2.1.2.4 Facsimile services

6.5.2.1.2.5 Short Burst Data Services (SBD)
- 1960 bytes / message (MO) and 1890 bytes / message (MT)
- Latency: 5 -20 seconds

6.5.2.1.2.6 Navigation and paging services

6.5.2.2 ICO

ICO will provide global mobile communications services using a constellation of medium earth orbit (MEO) satellites and a global ground telecommunications network. ICO is planning a family of quality voice, wireless Internet and other packet-data services. ICO also intend to provide other data communications services, such as global real-time and near real-time two-way messaging services.

Information on commercialization of services is not confirmed.

6.5.2.2.1 Specifications

6.5.2.2.1.1 12 Satellites (10 active) in MEO (Altitude: 10,390 km or 6,259 miles)
6.5.2.2.1.2 orbital planes with 6 each satellites
6.5.2.2.1.3 Orbit period is 361 minutes
6.5.2.2.1.4 Bands of operation
- 1980 - 2010 MHz ← →Mobile downlink frequencies
- 2170 - 2200 MHz ← → Mobile uplink frequencies
- 5/7 GHz ← → Satellite – ground communications

6.5.2.2.1.5 Multiple access scheme – TDMA
6.5.2.2.1.6 Uses bent-pipe architecture
6.5.2.2.1.7 Data rates support in future: 144 kbps
6.5.2.2.1.8 Voice circuit capacity per satellite: 4500

6.5.2.2.2 Services

6.5.2.2.2.1 Voice
- Transmission at 4800 bps

6.5.2.2.2.2 Data
- Data rate: 2400-9600 bps

6.5.2.2.2.3 Fax
6.5.2.2.2.4 SMS

6.5.2.3 GlobalStar

GlobalStar is a low-earth orbit (LEO) satellite-based telecommunications system founded by Loral Corporation and Qualcomm Inc. that will fill gaps between terrestrial wireless systems with low-cost, high-quality digital telecommunications services.

GlobalStar is available commercially since late 1999.

6.5.3.1 Specifications

6.5.3.1.1 48 satellites in LEO (Altitude: 1,414km or 876 miles)
6.5.2.3.1.2 Satellites are placed in 8 orbital planes
6.5.2.3.1.3 Orbital period of 113.8 minutes
6.5.2.3.1.4 Band of frequencies
- 2483.5 - 2500.0 MHz (S-band) ← → Mobile downlink frequencies
- 1610.0 - 1626.5 MHz (L-band) ← → Mobile uplink frequencies
- 6875 – 7055 MHz ← → Satellite – ground gateway (DL)
- 5091 – 5250 MHz ← → Ground gateway - satellite

6.5.2.3.1.5 Mobile Access scheme – CDMA
6.5.2.3.1.6 System software on the ground
6.5.2.3.1.7 Use bent-pipe architectures
6.5.2.3.1.8 2800 circuits per satellite
6.5.2.3.1.9 Qualcomm GSP1600 handsets costs between $400-$600

6.5.2.3.2 Services

6.5.2.3.2.1 Voice
- Adaptive 2400 / 4800 / 9600 bps
- Voice mail boxes
- Supplementary services (Call forwarding)

6.5.2.3.2.2 Data
- 9600 bps
- High data rate (up to 144Kbps) products are available

6.5.2.3.2.3 Fax
6.5.2.3.2.4 Paging
6.5.2.3.2.5 Position location
- Provides latitude and longitude of the user's current position with an accuracy of up to 10kms / 6 miles

6.5.2.4 SkyBridge

SkyBridge is a bandwidth provider. SkyBridge satellites are designed to offer access to broadband and narrowband services globally. The equivalent capacity of the system, defined as the total instantaneous broadband traffic at peak hours, is over 200 Gbps.

At present, SkyBridge project is on an indefinite hold.

6.5.2.4.1 Specifications

6.5.2.4.1.1 80 satellite system, consist of two "sub-constellations" of 40 satellites each
6.5.2.4.1.2 LEO system (Altitude: 1469 Km or 913 miles)
6.5.2.4.1.3 Orbital period of 115.3 minutes
6.5.2.4.1.4 Band of frequencies
  ▪ 10.7 to 12.75 GHz (Ku Band) ← → Mobile uplink frequencies
  ▪ 12.75 to 14.5 GHz (Ku Band) ← → Mobile downlink frequencies
6.5.2.4.1.5 System to employ the bent pipe approach
6.5.2.4.1.6 Each satellite to have 18 spot-beams for carrying uplink and downlink data traffic
6.5.2.4.1.7 Maximum system capacity: 200 Gbps
6.5.2.4.1.8 Maximum data rate per user
  ▪ Uplink: 9.6 Kbps
  ▪ Downlink: 24 Kbps

6.5.2.4.2 Services

6.5.2.4.2.1 Voice
6.5.2.4.2.2 Data
6.5.2.4.2.3 Video conferencing
6.5.2.4.2.4 Multimedia Applications over Broadband Internet

6.5.2.5 Inmarsat
International Maritime Satellite is an organization which provides maritime communications via four satellites over the Pacific, Atlantic and Indian oceans. Inmarsat intend to support the new Broadband Global Area Network (B-GAN), to be introduced in 2005 to deliver Internet and intranet content and solutions, video on demand, videoconferencing, fax, e-mail, phone and LAN access at speeds up to 432kbit/s almost anywhere in the world.

6.5.2.5.1 Specifications

6.5.2.5.1.1 4 Satellites in GEO (35,786 km)
6.5.2.5.1.2 Band of frequencies

- 1636.5MHz to 1645MHz ← → Mobile uplink frequencies
- 1535MHz to 1543.5MHz ← → Mobile downlink frequencies

6.5.2.5.1.3 Supported data rates at present: 64 Kbps

6.5.2.5.1.4 Mini-M land mobile: $3000

6.5.2.5.1.5 Provide global coverage except poles

6.5.2.5.1.6 System employs bent pipe architecture for routing the calls

6.5.2.5.2 Services

6.5.2.5.2.1 Web surfing

6.5.2.5.2.2 Voice telephony at 64Kbps

6.5.2.5.2.3 Facsimiles services

6.5.2.5.2.4 Vehicle cargo tracking

6.5.2.5.2.5 Flight deck communications

6.5.2.5.2.6 Distress and safety solutions for seafarers

6.5.2.5.2.7 Supply chain management

6.5.2.6 Thuraya

Thuraya offers cost-effective satellite-based mobile telephone services to nearly one third of the globe. Through its dynamic dual mode handsets and satellite payphones, Thuraya enable movement between cellular and satellite networks seamlessly. Thuraya's coverage spans Europe, North and Central Africa, the Middle East, the CIS countries and South Asia. It intends to cover rest of Asia by year-end 2004.

6.5.2.6.1 Specifications

6.5.2.6.1.1 2 Satellites in GEO (1 operational at a time)

- 1525.0-1559.0MHz ← → Mobile downlink frequencies
- 1626.5-1660.5MHz ← → Mobile uplink frequencies
- 3400.0-3625.0MHz ← → Satellite – ground gateway (DL)
- 6425.0-6725.0MHz ← → Ground gateway – satellite

6.5.2.6.1.2 Maximum data rate supported: 9.6Kbps

6.5.2.6.2 Services

6.5.2.6.2.1 Voice

6.5.2.6.2.2 Fax at 9.6 Kbps

6.5.2.6.2.3 Data at 9.6 Kbps

6.5.2.6.2.4 Short messaging

6.5.2.6.2.5 Location determination (GPS)

6.5.2.7 Orbcomm

Orbcomm provides global two-way digital monitoring, tracking and messaging services through the Low-Earth-orbit satellite-based data communications system.

6.5.2.7.1 Specifications

6.5.2.7.1.1 36 Satellites in LEO (Altitude: 825 km or 509 miles)
6.5.2.7.1.2 Bands of operation
- 148.00 - 150.05 MHz (Uplink)
- 137.00 - 138.00 MHz (Downlink)

6.5.2.7.1.3 Message size: 6-250 bytes typical
6.5.2.7.1.4 Addressing used in messages: Internet and X.400
6.5.2.7.1.5 Power output by communicator: 5 W

6.5.2.7.2 Services

6.5.2.7.2.1 Messaging Services (data rates)
- 2400 bps subscriber uplink
- 4800 bps subscriber downlink
- 9600 bps subscriber downlink (future)

6.5.2.7.2.2 Spacecraft commanding and telemetry via VHF at 57.6 kbps
6.5.2.7.2.3 Monitoring and controlling assets at remote sites
6.5.2.7.2.4 Tracking and managing construction equipment, locomotives, rail cars, trucks, trailers, shipping containers, marine vessels, aircraft and locating and recovering stolen vehicles and cargo
6.5.2.7.2.5 Weather data for general aviation

6.5.3 Cellular Communications

Cellular mobile communications system uses a large number of low-power wireless transmitters to create cells - the basic geographic service area of a wireless communications system. Variable power levels allow cells to be sized according to the subscriber density and demand within a particular region. As mobile users travel from cell to cell, their conversations are handed off between cells to maintain seamless service. Channels (frequencies) used in one cell can be reused in another cell some distance away. Cells can be added to accommodate growth, creating new cells in un-served areas or overlaying cells in existing areas.

6.5.3.1 GSM

GSM is one of the prevalent second-generation technologies. Others are D-AMPS and cdmaOne (based on IS-95 standard). GSM is the most widely used of the three digital wireless telephone technologies (TDMA, GSM and CDMA), and

it supports voice, data, text messaging and cross-border roaming. GSM support lower data rates through circuit switching.

DCS1800 and PCS1900 are similar to GSM900 in terms of the specifications. The main difference is the frequency of operation as described below. Even though the specifications are same, RF characteristics are different and hence a multi-band handset is required to get the services from these three different networks. DCS1800 is operational in Europe, Asia and Africa; on the other hand PCS1900 is operational in North America.

ETSI (European Telecommunications Standard Institute) later standardized GSM400 and GSM850 as well with similar specifications. All these additions served to increase the density of users without suffering from interference problems owing to frequency re-use.

6.5.3.1.1 Specifications

6.5.3.1.1.1 GSM operates in multiple frequency bands. GSM 900 is the popular one. Specified frequency bands:
- **GSM 400**: (a) 450.4 - 457.6 MHz paired with 460.4 - 467.6 MHz
- (b) 478.8 - 486 MHz paired with 488.8 - 496 MHz
- **GSM 850**: 824 - 849 MHz paired with 869 - 894 MHz
- **GSM 900**: 880 - 915 MHz paired with 925 - 960 MHz
- **GSM 1800 [DCS1800]**: 1710 - 1785 MHz paired with 1805 - 1880 MHz
- **GSM 1900 [PCS1900]**: 1850 - 1910 MHz paired with 1930 - 1990 MHz

6.5.1.1.2 Total number of frequency pairs: 124 (in GSM 900 band). In general adjacent cells do not operate on similar frequencies to avoid interference issues. This is known as cell planning.

6.5.3.1.1.3 Each frequency channel: 200 KHz with 8 Time slots per carrier [GSM900, DCS1800, PCS1900]

6.5.3.1.1.4 FDD technology - Duplex distance:
- GSM 900: 45 MHz
- DCS1800: 95 MHz
- PCS1900: 80 MHz

6.5.3.1.1.5 Multiple access scheme: TDMA/ FDMA

6.5.3.1.1.6 Modulation: Gaussian minimum shift keying (GMSK)

6.5.3.1.1.7 Transmission rate:
- User data per time slot: 260 bits per 20 ms. (equivalent to 13Kbps)
- Data after block coding and convolution coding: 456 bits per 20 ms (equivalent to 22.8 Kbps)
- Post modulation, bit rate: 33.8 Kbps per channel
- Symbol rate: 270 K bauds/sec per carrier (1 carrier = 8 slots)
- Over the air bit rate: 270 kbps per carrier [1 symbol = 1 bit]

6.5.3.1.1.8 Channel coding
- Block coding
- Convolutional coding (1/2, 2/3, 3/4)

- Interleaving scheme for burst errors

6.5.3.1.1.9 Frequency hopping is supported

- Offers a significant benefit of interference averaging
- Reduces the effects of fast radio signal fading

6.5.3.1.1.10 Speech rate: 13Kbps (Rest error-detection/ correction)

6.5.3.1.1.11 Normal GSM - Data rates - 9.6Kbps (only one channel at a time)

6.5.3.1.1.12 HSCSD (High Speed Circuit Switched Data): Data rate - 56Kbps (4 channels at a time)

6.5.3.1.1.13 No simultaneous transmission and reception

6.5.3.1.1.14 Half rate (6.5Kbps) voice channels are supported by more efficient speech coding

6.5.3.1.1.15 Discontinuous (DRX) mode is supported for efficient battery usage

6.5.3.1.1.16 Maximum output power, known as power class is fixed but the base station regularly adjusts output power at any point of time by sending appropriate commands. This also reduces interference with nearby cell sites, operating on same frequencies

6.5.3.1.1.17 A single GSM cell is capable of providing coverage over a maximum distance of 35 Km radiuses.

6.5.3.1.2 Services

6.5.3.1.2.1 Voice: Speech is encoded at 13 kbps

6.5.3.1.2.2 Data: Maximum data rates - 9.6Kbps

6.5.3.1.2.3 HSCSD: Maximum data rates – 56 Kbps

6.5.3.1.2.4 SMS: 160 characters per message

6.5.3.1.2.5 Facsimile group III

6.5.3.1.2.6 Cell broadcast

6.5.3.1.2.7 Voice mail

6.5.3.1.2.8 Supplementary services: Call forwarding, barring of calls, call hold and wait etc.

6.5.3.2 GPRS

General Packet Radio Services (GPRS) is a packet based wireless communication service that promises data rates from 56 up to 114 Kbps and continuous connection to the Internet for mobile phone and computer users connected via mobile. It belongs to 2.5G. GPRS is also known as Data GSM as it is an addition to traditional GSM technology. In other words, GPRS uses the same wireless infrastructure of GSM with some additional hardware in the network. Consequently most of the specifications of GPRS remain same as of GSM.

The capacity of every TDMA channel of GSM has been increased in GPRS by introducing a number of coding schemes. Depending on the user's requirement and the condition of the channel, a coding scheme is offered to a requested data

call. Effectively the user is allotted the TDMA channels of GSM but the selection of coding scheme and the allocation of multiple TDMA channels improve the data rate offered to the call. The network manages the seamless allocation or sharing of resources.

6.5.3.2.1 Specifications

6.5.3.2.1.1 Four different coding schemes: CS1 (9 Kbps), CS2 (13.4 Kbps), CS3 (15.6 Kbps) and CS4 (21.6 Kbps). CS1 is the same as used in traditional GSM system for normal data transmission. CS1 is used for carrying control messages.
6.5.3.2.1.2 Reserves radio network bandwidth only during transmission. Multiplex many users on the same TDMA channel results in efficient sharing of air resources.
6.5.3.2.1.3 Voice TDMA channels are not shared with data TDMA channels. However dynamic allocation of channel to different type of traffic is supported in the network.
6.5.3.2.1.4 Asymmetric data traffic is supported. Maximum 8 time slots in one direction.
6.5.3.2.1.5 Maximum data rates: 113.6 Kbps (theoretically 172.8 Kbps)

6.5.3.2.2 Services

6.5.3.2.2.1 Allows simultaneous voice and data calls
6.5.3.2.2.2 In general, low protection (CS3/CS4) for non-real time data as retransmissions can take care of erroneous delivery. Real time applications such as voice and video are provided high protection (CS1/CS2).

6.5.3.3 EDGE

EDGE (Enhanced Data rates for Global Evolution) is the next step in the evolution of GSM and IS-136. It has increased the data rates by many folds and has improved the spectrum efficiency. EDGE introduces a new modulation technique and new channel coding that can be used to transmit both packet-switched and circuit switched voice and date services. EDGE is therefore an add-on to GPRS (sometimes also known as EGPRS).

6.5.3.3.1 Specifications

6.5.3.3.1.1 EDGE operates in the same frequency band as GSM or GPRS.
6.5.3.3.1.2 Modulation: 8-PSK (good radio conditions) / GMSK (poor radio conditions)
6.5.3.3.1.3 Nine additional coding schemes: MCS1 – MCS9. MCS1- MCS4 uses GMSK while MCS5- MCS9 uses 8-PSK modulation (MCS1: 6.5Kbps, MCS2: 11.2Kbps, MCS3: 14.8Kbps, MCS4: 17.6 Kbps, MCS5: 22.4 Kbps, MCS6: 29.6 Kbps, MCS7: 44.8Kbps, MCS8: 54.4 Kbps, MCS9: 59.2 Kbps)

6.5.3.3.1.4 Convolutional coding varies from 0.53(MCS1) to 1(MCS9)

6.5.3.3.1.5 Transmission rate:

- Initial user data is variable depending upon the coding scheme used.
- Symbol rate: 270 K bauds/sec per carrier (1 carrier = 8 slots)
- Over the air bit rate: 810 kbps per carrier [1 symbol = 3 bit]

6.5.3.3.1.6 Data rates: 384 Kbps equivalent to 48 Kbps per time slot (theoretically 473.6 kbps equivalent to 59.2 Kbps achievable with MCS9)

6.5.3.3.1.7 Simultaneous support for multiple modulations (GMSK/8PSK) on time slots of a single carrier frequency is provided

6.5.3.3.1.8 EDGE support more users per time slot than GPRS

6.5.3.3.1.9 EDGE is more sensitive to interferences and noise

6.5.3.4 UMTS/ CDMA 2000

UMTS and CDMA2000 belong to 3rd generation technologies of digital wireless communications. The two technologies are a consequence of the standardization effort initiated by IMT-2000 (a body created by ITU-T) for working out a new air interface that could result in efficient frequency usage in comparison to GSM, cdmaOne and D-AMPS. UMTS (W-CDMA) is developed by Ericsson and is used in Europe while CDMA2000 (evolved from IS-95) is developed by Qualcomm and is used in United States.

These two technologies target the convergence of fixed line telephony, mobile, Internet and computer technology. Targeted data rates are 2 Mbps.

6.5.3.4.1 UMTS Specifications & services

6.5.3.4.1.1 Multiple access schemes: DSSS [spreading factor (FDD): 4-512; higher the spreading factor - less susceptible to interference and lesser the data rate]

6.5.3.4.1.2 Two topologies: FDD (Frequency Division Duplex) involves pair of frequencies & TDD (Time Division Duplex also known as TDCDMA) with unpaired spectrum.

6.5.3.4.1.3 UMTS operates in a number of frequency bands:

- Characteristics of FDD
  - Uplink: 1920-1980 MHz
  - Downlink: 2110-2170 MHz [Duplex distance: 190 MHz]
  - Channel bandwidth: 5MHz
  - Each channel is a frame of duration:10 ms with 15 slots in it
  - A slot could be control channel or data channel (everything dynamic)
  - Chip rate: 3.84 Mcps
  - Raster: 200 KHz
  - Modulation: dual channel QPSK
- Characteristics of TDD

- Two bands: 1900-1920 and 2010-2025 MHz
- TX and RX are not separated in frequency
- Separate time slots for uplink and downlink transmissions
- Channel bandwidth: 5MHz
- Chip rate: 3.84 Mcps
- Raster: 200 KHz

6.5.3.4.1.4 A single channel of BW 5 MHz, 10 ms duration with a unique spreading code is capable of supporting 480Kbps on the uplink and 960 Kbps on the downlink. Several such channels (4-6) can co-exist on the same frequency using different spreading codes and combined to provide data rates of maximum 2 Mbps. This is applicable for both FDD and TDD topologies.

6.5.3.4.1.5 Data rates: Maximum 2 Mbps

6.5.3.4.1.6 Different modulation schemes on uplink and downlink channels.
- Downlink: QPSK [Control, voice and date channels]
- Uplink: Dual channel modulation on QPSK – I channel for data and Q channel for control information

6.5.3.4.1.7 AMR (Adaptive Multi Rate) speech coders are supported

6.5.3.4.1.8 Open loop and closed loop power control mechanisms are supported. User equipment is sent a power control command every 666 ms.

6.5.3.4.1.9 DRX is supported for efficient battery usage

6.5.3.4.1.10 Voice communications is conducted on two 5 MHz bands, one for uplink and one for downlink. However, no simultaneous transmission and reception is supported.

6.5.3.4.1.11 The number of simultaneous connections any base station is able to handle is the result of a trade-off with the range of the base station and the quality of each connection. UMTS allows up to 100 voice calls and 200 data calls on a single 5 MHz channel. Each user is assigned a unique spreading sequence to differentiate.

6.5.3.4.1.12 Control channels use different spreading codes and hence co-exist with voice and data channels. Also control channels are dynamic in nature.

6.5.3.4.1.13 Control channels in UMTS have more capabilities than GSM control channels such as coordination of multimedia, high-speed packet data, broadcast messaging and fast power control.

6.5.3.4.2 CDMA2000 specifications and services

6.5.3.4.2.1 CDMA2000 can operate in any assigned cellular band in addition to frequencies assigned by IMT.

6.5.3.4.2.2 CDMA2000 represents two families of technologies:
- CDMA2000 1X: 144 Kbps
- CDMA2000 1xEV: 2 Mbps

6.5.3.4.2.3 Channel bandwidth: Multiples of 1.25 MHz (typical ones are 1.25 MHz and 3.75 MHz; multiples supported: 1, 3, 6, 9 & 12; Max: 15 MHz)

6.5.3.4.2.4 FDD/CDMA2000 uses paired multiples of 1.25 MHz (one for Uplink and one for downlink).

6.5.3.4.2.5 Each radio channel assigned to a user is composed of multiple physical carriers, each having a unique code (spreading sequence).

6.5.3.4.2.6 Each channel of 1.25 MHz is capable of providing a maximum of 307.2 Kbps data rate. Three such channels with in a 5 MHz bandwidth can provide a data rate of 1036.8 Kbps

6.5.3.4.2.7 Chip rate: 1.288 Mcps (1X); 3.6864 Mcps (3X)

6.5.3.4.2.8 Spreading factor: 4-256 uplink

6.5.3.4.2.9 Open loop and closed loop power control mechanisms are supported. User equipment is sent a power control command every 1.25 ms.

6.5.3.4.2.10 Mobiles transmit and receive simultaneously during a voice conversation.

6.5.3.4.3 Services (both UMTS and CDMA2000)

6.5.3.4.3.1 High quality voice transmission

6.5.3.4.3.2 Messaging (replacing e-mail, SMS, fax etc.)

6.5.3.4.3.3 Multimedia (playing music, viewing videos etc)

6.5.3.4.3.4 Internet access

6.5.3.5 TD-SCDMA

Time Division Synchronous CDMA (TD-SCDMA) was proposed by China Wireless Telecommunication Standards group (CWTS) and approved by the ITU in 1999. The technology is being developed by the Chinese Academy of Telecommunications Technology and Siemens.

TD-SCDMA uses the Time Division Duplex (TDD) mode, which transmits uplink traffic and downlink traffic in the same frame in different time slots. That means that the uplink and downlink spectrum is assigned flexibly, dependent on the type of information being transmitted. When asymmetrical data like e-mail and internet are transmitted from the base station, more time slots are used for downlink than for uplink. A symmetrical split in the uplink and downlink takes place with symmetrical services like telephony.

6.5.3.5.1 Specifications & services

6.5.3.5.1.1 Frequency band: 2010 MHz - 2025 MHz

6.5.3.5.1.2 Channel bandwidth: 1.6 MHz

6.5.3.5.1.3 Chip rate: 1.28 Mcps

6.5.3.5.1.4 Frame duration: 10ms

6.5.3.5.1.5 Modulation: QPSK or 8PSK

6.5.3.5.1.6 Employs a single carrier to both send and receive traffic

6.5.3.5.1.7 Support voice at 8Kbps

6.5.3.5.1.8 Support packet data at 9.6kbps, 64kbps, 144kbps, 384kbps, 2048kbps

6.5.3.5.1.9 Multiple access scheme: Essentially a TDMA-TDD system but also support TDMA with adaptive CDMA

6.5.3.5.1.10 Adaptive resource (uplink and downlink slots) management leading to improvement in capacity

6.5.3.5.1.11 Spreading factor supported: 1, 2, 4, 8 and 16

6.5.3.6 Wireless in Local Loop

WLL is a communications access method that uses radio waves for the transmission of information between customers and service provider exchange or central office. This is unlike the traditional methods where a fixed copper line (known as the local loop) is used to connect the subscriber to the nearest local exchange.

Connection is basically a LOS communication between the local exchange and the antenna installed at the customer's premises. Since WLL is a wireless access method that uses radio waves to connect the subscriber to a local central office, it can be implemented alongside a regular PSTN (Public Switched Telephone Network), or combined with digital wireless technologies. WLL is capable of offering data-rate of Mbps i.e., broadband and multimedia-rich content on handheld.

6.5.3.6.1 Specifications & services

6.5.3.6.1.1 Multiple access schemes: CDMA

6.5.3.6.1.2 WLL operates in multiple frequency bands:
  ▪ 1.3 GHz (in United States)
  ▪ 40 GHz (in Europe)

6.5.3.6.1.3 Data rates: 144 Kbps

6.5.4 Wireless technologies used in identification & tracking

The value of knowing where the vehicles (and all important contents they are carrying) are, anytime, together with the expected time of arrival at their destinations, is enormous. Currently some logistic and road haulage firms incur financial penalties for late deliveries, so the idea for investing in some type of technology enabled tracking has always been good.

Wireless solutions have the potential to improve the supply chain visibility using traditional cell-phone or other technology. These technologies provide various benefits including directing and confirming deliveries and pick-ups for packages, providing last mile tracking to extend visibility of products within the supply chain, accurately managing asset inventories with flexible, efficient counting processes that eliminate the paper trail, automating and managing replenishment inventories for remote storage locations (carts, trucks, etc.), tracking all material

entering, and capturing and storing all necessary information about materials and processes.

6.5.4.1 RFID

Radio Frequency Identification belongs to a group of technologies called Automatic Identification and Data Capture. It is a means of capturing data about an object without using a human to read the data.

An RFID system is always made up of two components, a tag or a transponder and an interrogator or reader, as shown in figure below. A reader/interrogator/scanner transmits an RF wave to a tag. The tag "hears" the RF wave, and responds with some data. Tag is basically comprised of an IC and an antenna (also known as coupling element). IC could include memory and some form of processing capability. The memory could be read only or read/write. Tag talks to the interrogator using an air-interface. It specifies the protocol of communication and also includes the frequency of the carrier, the bit data rate, the method of encoding and other relevant parameters. Low frequency tags often use coils of wire, whereas high frequency tags are usually printed with conducting inks.
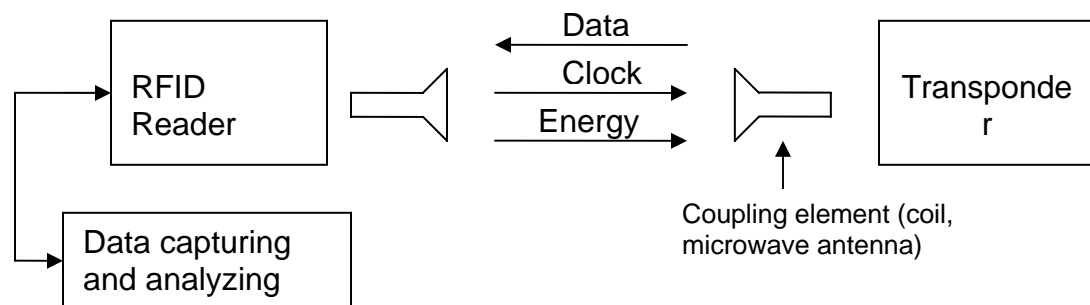
Figure 6.5.1: RFID system

6.5.4.1.1 Specifications

6.5.4.1.1.1 Categories of RFID tags:
- Near field: These employ inductive coupling to the reactive energy (localized oscillatory magnetic fields) circulating around the reader antenna. Other characteristics include:
  o Generally applied to RFID operating in LF and HF bands
  o Energy coupling mechanisms are purely magnetic
  o Range $\leq \gamma/2\pi$ (where γ is the wavelength depends on resonating frequency of the tag). This range is also known as radian sphere.
  o Reasonably high Q-factor (30-80)
  o Vulnerable to metals and dielectric mediums causing detuning (shift in resonance frequency shifting). It may

cause reduction in transponder sensitivity and reading distance. Detuning also crops up when tags are in close physical proximity to each other.
- o Higher operating speeds in comparison to far field tags
- Far field: Tags working in this category get energy from the real power contained in free space propagating electromagnetic plane waves. Other characteristics include:
  - o Generally applied to RFID in UHF and microwave bands
  - o Longer read range $\geq \gamma/2\pi$
  - o Power requirements of reader/interrogator increases

Table 6.5.2: Technology Range

	Near Field	Far Field
Frequency	100KHz – 30MHz	2.45-5.8GHz
Range	3 meters	2-15 meters
Technology	Inductive coupling	EM waves
Data rate	Low	High
Battery requirements	No	Yes

6.5.4.1.1.2 Energizing RF field can also provides the necessary timing information (synchronization) to tag's internal system clock.

6.5.4.1.1.3 Tags come in many flavors:
- Passive tags: These tags get all their power from the signal sent by the interrogator. These use radio waves to collect the data and convert it into power. The tag is only powered when it is in the beam of the interrogator. The tag then uses a technique called backscatter to reply to the interrogator. This does not involve a transmitter on the tag, but is a means of "reflecting" the carrier wave and putting a signal into that reflection.
- Battery assisted: These tags are just like passive tags (and they use backscatter) but they have a battery to provide the power to the chip. This provides a big advantage, because the tag is not dependent on the strength of the carrier from the interrogator to provide the power it needs. Now it can use all the power from the battery and so is able to work at a greater distance from the interrogator.
- Active tags: These tags have not only a battery, but also some form of transmitter on the tag. It can talk over a long range.

6.5.4.1.1.4 RFID operates in several frequency bands. Each of the frequency bands has advantages and disadvantages for operation. The generic frequencies for RFID are:
- 125 to 134 KHz
- 13.56 MHz
- UHF (400 – 930 MHz)
- 2.45 GHz

- 5.8 GHz

6.5.4.1.1.5 Memory sizes:
- 1 bit (surveillance applications)
- 64 bits (storing IDs)
- Several KB (applications specific)

6.5.4.1.1.6 Memory types:
- Read-only (storing IDs)
- One time field programmable
- Read/write tags

6.5.4.1.1.7 Anti-collision protocol can allow many tags in a field to talk at the same time.

6.5.4.1.1.8 Allows reprinting of information

6.5.4.1.1.9 Works well in harsh conditions

6.5.4.1.1.10 RFID based on 13.56 MHz have this property that water and human beings do not absorb RF field

6.5.4.1.1.11 Lightweight

Applications

RFID is used in applications such as preventing theft of automobiles, collecting tolls without stopping, managing traffic, gaining entrance to buildings, automating parking, controlling access of vehicles to gated communities, corporate campuses and airports, dispensing goods, providing ski lift access, tracking library books, buying hamburgers, and the growing opportunity to track a wealth of assets in supply chain management.

6.5.4.2 RTLS

RTLS is RFID upgraded to produce instant location information of the tagged items.

Items tagged with normal RFID are read when a reader is brought near a tag or a tagged item is passed near a reader. RTLS allows a network of reader units to calculate the actual location of a tagged item, without the tagged item being near the reader. Using special readers placed around a property, tags are located using a triangulation system. Tagged items may be as small as a tool or as large as a trailer truck.

RTLS readers are usually deployed as a matrix of readers that are installed at a spacing of anywhere from 50 to 1000 feet. The system continually updates the database with current tag locations as frequently as every several seconds, or as infrequently as every few hours for items that seldom move. Most RTLS tag transmissions come from a combination of timed intervals, tag movement, low battery warning, and

response to inquirers from the reader system. The frequency of tag location updates may have implications for the number of tags that can be deployed and the battery life of the tag. A typical applications system can track thousands of tags simultaneously and the average tag battery life can be three to four years.

Real Time Locating Systems address the weaknesses of conventional supply chain management systems with wireless technology, providing instantaneous location, tracking, and management of supply chain resources.

Applications

- Supply chain management
- Manufacturing
- Healthcare: Locate hospital personnel instantly and track patients and keep them Safe
- High value asset security: RTLS supports software alarms to provide notification when something has moved. For instance, a tag on a high value asset can signal an alert if the asset starts to move so that it can be located and stopped before it is removed from the facility. Similarly a tag on a process control batch can trigger an alert if the batch does not move to the next process within a specified period of time.

6.5.4.3 Global Positioning System

GPS is a satellite navigation system designed to provide instantaneous position, velocity and time information almost anywhere on the globe at any time, and in any weather. The principle behind GPS is the measurement of distance (or "range") between the receiver and the satellites. Periodically GPS transmits these specially coded satellite signals that are processed by a GPS receiver, enabling it to compute position, velocity and time. In general, four GPS satellite signals are used to compute positions in three dimensions and the time offset in the receiver clock. This method of estimating the co-ordinates is also known as triangulation. The satellites also send the information regarding their present location in their orbits above the Earth.

The nominal GPS operational constellation consists of 24 satellites that orbit the earth in 12 hours. These Satellites orbit at a height of 20,183 km above the Earth. These satellites orbit in 3 orbital planes. GPS comprises three main components: the control segment, the space segment and the user segment.

GPS satellites transmit two L-Band signals, which can be used for positioning purposes. This is done to eliminate the errors introduced by

ionospheric refraction. Frequencies used to generate these signals are 1575.42 MHz and 1227.60 MHz and are often called the carriers.

Applications

- Determination of location is the primary use
- Provide navigation information for ships and planes
- GPS is also very handy in tracking. This application is widely used in tracking the fleets of vehicles that are used to deliver goods and services either across a crowded city or through nationwide corridors.
- GPS is a very helpful technology, assisting vehicle drivers in the estimation and development of maps for reaching the destination without wasting any time.
- GPS also transmits highly accurate atomic clock times

6.5.4.4 Cellular based tracking

It is a non-GPS method for tracking the location of an entity. Several radio network-based systems, which accurately measure the time difference (TDOA or EOTD) or time of arrival (TOA) of wireless radio transmissions have been developed and tested with good results. Time measurement systems depend on network overlays of additional radio transmissions, which require expensive atomic clocks and special location measurement hardware integrated into the cell site Base Stations. However these implementations require high costs for the cellular operators.

A more cost effective solution for location positioning is one that can be based on existing radio signal data measurement from a series of base stations to a mobile device. The advantage of this approach is that only existing wireless signal data is analyzed, so no new hardware (network or handset) is required. However, significant signal level variations and multipath effects have proved a major obstacle to many developers.

Another way of locating the handset is by monitoring the Cell ID of its present location. This method however, does not provide the precise information. In urban areas, where the networks are denser, this way of tracking can provide the information about the handset to an accuracy of few hundred meters. This solution does not require any up gradation of software in handset and no additional expenditure on the part of the operator.

Applications
- Tracking of shipments, making the supply chain visible and transparent
- Track the availability of drivers and can schedule the allocation of new jobs on the basis of that.
- Provide the driver with the routing information
- Provide driver with the traffic information
- Tracking thefts etc.

6.5.5 Conclusion with application examples from businesses

A. Short range wireless technologies

Criterion for the selection of a technology driven by a target application depends on a number of factors. These are operating frequency, bandwidth (data rates), range, security requirements, memory capacity, user density, power consumption, ease of deployment, ease of integration, weight, dimensions and ambience. These factors have been compared in the table below.

Table 6.5.3: Comparison: Short-range wireless communications

	Bluetooth	Wi-Fi			802.15.4	Home RF	IrDA	UWB Radio
		802.11a	802.11b	802.11g				
Primary purpose	Wireless data exchange (WPAN solution)	Wireless connectivity to Internet (WLAN solution)			Low bandwidth, very low power wireless data exchange	Wireless voice and data exchange within house	Short range data exchange	Short range, High bandwidth data exchange
Frequency	2.4 GHz	5 GHz	2.4 GHz	2.4 GHz	0.8GHz/ 0.9GHz/ 2.4GHz	2.4 GHz	1000 GHz	3.1 GHz – 10.6 GHz
Maximum coverage range (m)	10	16-18	90	20-90	10	45	2	10
Data rates	723.2 Kbps	54 Mbps	11 Mbps	11-54 Mbps	10-250 Kbps	10 Mbps	16 Mbps	480 Mbps
Cost of equipment	$5 - $10	$50	$25-$50	$50	$5	-	$2	-
Power requirements	1mW - 100mW	50mW – 1W	100mW	100mW	Very low power	100mW	Low	250mW
Security	Secured (using ciphering & session keys)	Secured (using WEP) but could be broken easily			Secured (CCM integrity/ encryption)	Secured (56 - bit encryption algorithm	Yes (CRC-16 & CRC-32)	Highly secured

Suffer from interference	Negligible due to frequency hopping	Less (frequency band is less crowded)	Yes	Yes	Yes	Yes	No	No
LOS requirements (if any)	No	No	No	No	No	No	Yes	Yes
Voice support	Yes	Supported using VoIP	Supported using VoIP	Supported using VoIP	No	Yes	Supported using VoIP	Supported using VoIP
Operational	Yes	Yes	Yes	Yes	Yes	Yes	Yes	2004
Devices supported	Printers, cameras, cell phones, PDAs, other peripherals	Laptop computers, PDAs, cell phones	Laptop computers, PDAs, cell phones	Laptop computers		Laptops, cordless telephones, peripherals & other consumer devices	PCs, laptops & peripherals	Laptops
Other supported services					Wireless home security, Wireless connectivity to peripherals			Video conferencing, wireless video, diskless computers

The following conclusions can be made:

1. 802.11b is the only technology that's capable of offering solution beyond 50 meters. It can be offered up to a distance of 80-90 meters at achievable data rates of 5-6 Mbps. However it is prone to security breach as the encryption incorporated using WEP is breakable. 802.11b is also prone to interference with Bluetooth, HomeRF and 802.15.4 as all of these operate in the same frequency band.

2. In terms of data rates, 802.11a and UWB radio clearly standout as winners. Where 802.11a is capable of offering data rates of 54Mbps, UWB radio is targeted to offer data rate of up to 450 Mbps. Another advantage with 802.11a and UWB radio is that these technologies are not prone to interference. Lastly, UWB radio is more secure than 802.11a. 802.11a has enhanced WEP encryption algorithm but is still prone to spoofing and attacks. However it shall be noted that specifications for UWB radio is still being researched.

3. Bluetooth, IEEE 802.15.4, HomeRF, IrDA and UWB are popular choices for very short distance wireless data communications. IrDA operate at 1000 GHz and it is capable of providing data communications over a maximum distance of 2 meters. These characteristics account for highly secured data transmission with IrDA. Additional security is implemented by the use of CRC-16 and CRC-32. The implementation of these technologies is comparatively simple and that of IrDA is the simplest.

4. Power consumption is lowest with IrDA. Bluetooth is the next best candidate. However if the data requirements are not very high (maximum 250 Kbps), then IEEE 802.15.4 is capable of serving for months.

5. Between 802.11a and 802.11b, selection of a particular standard could be driven by these facts:

   a) Superior bandwidth of 802.11a offers excellent support for bandwidth hungry applications, but the higher operating frequency equates to relatively shorter range. In general, 802.11a is good for supporting higher end applications involving video, voice, and the transmission of large images and files.

   b) 802.11b offers a bigger coverage. Therefore it is an inexpensive solution for larger facilities such as warehouse or department store because it would require fewer access points. If there are relatively few end users that need to roam throughout the entire facility, then 802.11b will likely meet performance requirements because there are fewer end users competing for each access point's total throughput. Unless there are significant needs for very high performance per end user, then 802.11a would probably be overkill in this situation. Essentially 802.11b is a good solution if fewer users are competing for a single access point.

   c) 802.11a operates in the 5 GHz band which is not as crowded as 2.4 GHz band. Therefore 802.11a is not affected by interference.

   d) 802.11a is a good solution when the end users are densely populated. Only a fewer access points would be able handle these users.

   e) If all 802.11 devices are incurring similar power consumption, 802.11a & 802.11g consume much less energy than 802.11b for a given workload due to higher bandwidths and thus results in longevity of battery.

   f) Since 802.11a and 802.11b devices operate in different frequency bands, they do not interoperate. However the efforts have been initiated for the development of dual transceiver, dual chipset solution that would allow an end user to latch to any type of network.

6. Both Bluetooth and 802.11b have distinct applications. If the intended need is high performance, 802.11b is the way to go. But if you need the lowest cost easiest-to-use solution for a wide range of devices, then Bluetooth is the clear choice. Further between Bluetooth and 802.11b, former is less prone to interference even though both operate in the same frequency band.

7. 802.11 is suitable for real-time long-distance network access, however, it is not suitable for PDA due to its very high power consumption, which drains the battery very fast. IrDA is the solution.

B. Satellite Communications

Satellite communications systems are changing the way in which we explore, do our research, navigate, track, travel from place to place whether by land, sea or

air and whether in remote terrains or through congested city streets. Within a few years, all mobile phones will incorporate global positioning receivers as standard. The combination of being able to send a text message by mobile phone together with your precise location will have far reaching implications.

Another look at various applications promised by these satellite systems reveals how the offerings of data connectivity has provided the explorer, navigator with an added advantage. Now they do no have to store the result and process them at some later date. It is transferred instantaneously and analyzed, saving precious time. It has revolutionized the whole research process. Further discussing the applications of satellite communications in more detail, we can:

1. Distress and safety solutions for seafarers: Satellite navigation can be widely used to locate life rafts lost at sea or to keep tabs on explorers heading for isolated and little-known parts.
2. Flight deck communications
3. Monitoring and controlling assets at remote sites
4. Satellite navigation can help pilots to land planes safely, especially in poor weather conditions. At present, this is possible only with differential satellite navigation in which an antenna close to the runway transmits a signal to the navigational satellites.
5. Vehicle cargo tracking
6. Supply chain management
7. Provide weather data for general aviation
8. Satellite navigation can help regulate road use and minimize traffic jams.
9. Find our way in a foreign city

Each of the satellites system discussed above is offering data services. However, they do differ in their coverage, cost of service, reliability and data capacities. A table comparing these metrics is sketched below.

Table 6.5.4: Comparison: Satellite Communications

	Iridium	ICO*	GlobalStar	SkyBridge*	Inmarsat	Thuraya	Orbcomm
Primary purpose	Voice and data services	Voice and data services	Voice and data services	Data services	Voice and data service	Voice and data services	Messaging services
Frequency (Mobile-Satellite)	1616-1625.5MHz	1980-2010MHz (DL)/ 2170-2200MHz (UL)	2483.5-2500MHz (DL)/ 1610.0 - 1626.5MHz (UL)	10.7-12.75GHz (UL)/ 12.75-14.5GHz (DL)	1636.5-1645Mhz (UL)/ 1535-1543.5Mhz (DL)	1626.5-1660.5MHz (UL)/ 1525.0-1559.0MHz (DL)	148-150 MHz (UL)/ 137-138MHz (DL)

Frequency (Ground-Satellite	19.4 – 19.6 GHz (DL)/ 29.1-29.3 GHz (UL)	5-7 GHz	6875-7055MHz (DL)/ 5091-5250MHz (UL)	-	5900-6470MHz (UL)/3570-4215MHz (DL)	6425.0-6725.0MHz (UL)/ 3400.0-3625.0MHz (DL)	-
Orbit information	LEO(66 Satellites)	MEO(12 Satellites)	LEO(48 Satellites)	LEO(80 Satellites)	GEO(4 Satellites)	GEO(2 Satellites)	LEO(36 Satellites)
Data rates	2.4 Kbps (dial-up) 10Kbps (Direct Internet Data)	144 Kbps	9.6 Kbps/ 144 Kbps	9.6 Kbps (UL)/ 24 Kbps (DL)	64Kbps	9.6 Kbps	2.4Kbps(UL)/ 4.8Kbps(DL)
Coverage	Global	-	North and South America; Europe, parts of Asia, Australia	-	Global except poles	Europe, North & Cent. Africa, Middle East, & South Asia	Global
Voice support	Yes	-	Yes (adaptive 2.4/4.8//9.6 Kbps	Yes (VoIP)	Yes	Yes	No
Cost of handset (approx.)	$1500 + $400 (for data access)	-	$500 - $600	-	$3000	$900	$995
Other services	SMS, paging	SMS	Fax, SMS & Paging	-	Fax	Fax, short messaging	-
Applications	Navigation and paging services		Position location	Video conferencing, multimedia applications	Supply chain, Vehicle tracking, safety solutions	Location management	Spacecraft commanding & telemetry, controlling assets, tracking
Handset maker(s)	Motorola & Kyocera	Mitsubishi, NEC & Samsung	Ericsson, Qualcomm & Telit		Thrane &Thrane, Nera Worldphone	Hughes & Ascom	Magellan

There is many other satellite systems in the space apart from those discussed above. One is Eutelsat, operating with 22 GEO satellites and reaches into Europe, the Middle East, Africa, Asia, eastern North America and South America. Their system operates using Ku-band, Ka-band and C-band transponders. AMSC (American Mobile Satellite Communications) with AMSC-1 satellite and Canadian TMI Communications with MSAT-1 satellite form another satellite system. Together they provide satellite communication services over the whole of North America, including Alaska. ACeS (Asia Cellular Satellite) operate with one GEO satellite and provide coverage over the whole of Asia. These satellite systems also provide services to companies who specialize in solutions ranging from fleet management, tracking etc.

ICO and SkyBridge are not operational as of today.

C. Cellular Communications

The three network standards CDMA, GSM, and TDMA belonging to 2G were designed for voice services primarily. Even under ideal conditions, these networks transfer data at only 14.4 Kbps maximum. Increases in demand and the poor quality of service associated with these 2G systems led mobile service providers/ standard organizations to research ways to improve the quality of service and to support more users in their systems. Because the amount of frequency spectrum available for mobile cellular use was limited, efficient use of the required frequencies was needed for mobile cellular coverage.

2G technologies used circuit switched connections to provide data connectivity. Considering the burst nature of the Internet data, circuit switched data was obviously resulting in a highly inefficient mode of transmission. GPRS introduced the concept of packet switched data and it promised data rates of 114Kbps on the downlink provided all 8 time slots are used for reception. This development enabled text based services such as e-mails and simple web browsing on mobile phones. But this was still not enough as demands for multimedia applications on the mobile phones were growing. EDGE was proposed next to offer data rates up to 384Kbps. It should be noted that GPRS enabled and EDGE enabled handsets are required for deriving services from these networks. Presently a Finnish company TeliaSonera has started offering EDGE technology enabled faster mobile services.

UMTS and CDMA2000 provided further improvement in the efficient use of the spectrum. These two stressed on increasing the capacity of user that can be served in a cell along with enormous improvements in data rates. In general, the introduction of 3rd generation technologies brought about a complete overhaul of the 2G and 2.5G systems in term of the implementation. Other important comparisons and advantages of 3G over 2G technologies are captured in the table below.

Table 6.5.5: Comparison: Technologies

	GSM 900	GPRS	EDGE	WCDMA (UMTS)	CDMA 2000	IS-95	CDPD
Primary purpose	Mobile voice services (DCS1800 & PCS1900 are similar to GSM900)	Mobile data services	High BW data services	Voice & High BW data services	Voice & High BW data services	Voice services	Transmit data over analog cellular networks

Frequency band (MHz)	GSM 900 (880-915 UL / 935-960 DL) DCS1800 (1710-1785 UL/ 1805-1880 DL) PCS1900 (1850-1910 UL/ 1930-1990 DL)			FDD [1920-1980 UL 2110-2170 DL] TDD [1900-1920 & 2010-2025]	Any existing band plus the one assigned by IMT		800, 1900
Multiple access scheme	TDMA/FDMA			CDMA	CDMA	CDMA	-
Voice support	Yes (13 Kbps)	No	No	Yes	Yes	Yes (8 Kbps)	No
Data rates	9.6 Kbps (single slot)	114 Kbps (on 8 slots)	384 Kbps (on 8 slots)	2 Mbps	2 Mbps	9.6Kbps	19.2 Kbps (effective only 9.6 Kbps)
Channel bandwidth	200 KHz	200 KHz	200 KHz	5 MHz	1.25 - 15 MHz	1.25 MHz data channels	30 KHz
Additional comments	56 Kbps supported using HSCSD (4 TS multiplexed on CS-1)	Conventional GSM900 upgraded to support data services	Conventional GSM900 upgraded to support 8PSK modulation scheme	Supports 2 topologies: FDD & TDD	Enhancement to traditional IS-95 technology	30 KHz voice channels for backward compatibility with AMPS	
Devices supported	GSM 900 cell phones, PDAs	GPRS enabled cell phones, Laptops with 900 MHz transceivers and SIM	EDGE enabled cell phones, Laptops with 900 MHz transceivers and SIM	UMTS terminals	CDMA2000 terminals	CDMA mobiles, AMP mobiles, dual mode mobiles	Cellular phones, PDAs, pagers

Networks offering 3G services:

- NTT DoCoMo launched FOMA in October 2001 and become the world's first fully commercialized 3rd generation mobile service provider.
- Sprint PCS and Verizon wireless launched 3G networks (CDMA2000 1X) in 2002 offering data rates between 40 to 60 Kbps on the handset.
- South Korean telephone company SK Telecom is also building its first 3G wireless network in the country.
- Licenses have been awarded to many companies all around the world and many of these likely to launch in next 2 years.

With the introduction of these networks, video conferencing, and accesses to multimedia-rich sites, transfer of large files on mobile phones is soon going to be a reality.

D. Wireless solutions used in identification & tracking

A general overview on the available solutions was provided earlier. This section will discuss the implementation and advantages of these systems, assisted by examples of companies that have successfully implemented wireless and mobile technologies for different types of business solutions.

Additional note on tracking solutions:
GPS used for tracking: In this system, information about the shipment is tracked by installing the wireless communication device on every delivery vehicle. This way location of each vehicle is tracked and consequently the batch. This system requires an additional set of receiver and transmitter. Information on the current co-ordinates is collected by GPS terminal on the vehicle and then the transmitter wirelessly to the receiver, which is then translated into visually appealing maps, relays it. The price as well as the hassle associated with GPS is considerable and this investment has traditionally only been justified for logistic companies with over a hundred vehicles.

Cellular based tracking: As discussed above, tracking using cellular networks can be advised in a number of ways. The one based on cell ID is predominantly used by a number of companies in the world in their logistic operation merely because of the fact that it is quite inexpensive. In rural areas where the density is less, the location accuracy will be less but will still be fit for purpose. Cell Id based tracking isn't as accurate as GPS but in the future, the ability to exactly pin-point the location of assets could be enhanced via upgrades to the operator's core network.

Satellite based non-GPS system, used in tracking: In a GPS based tracking, GPS receiver receive signals from a collection of satellites, does some calculations to derive the co-ordinates of the receiver. In this solution, mobile terminal itself sends its ID to the satellites, which relays the transmission to the gateway ground station. Ground station then works on the collected data and determines the position of the mobile. SkyBitz is providing this solution using their patented technology, Global Locating System. SkyBitz is using AMSC satellite system for their solutions.

QualComm is using Eutelsat SA satellite system for their range of solutions in fleet management. Many companies for wireless asset tracking problems are using their solutions such as GlobalTRACS and OmniTRACS.

Business practices implementing wireless solutions:
UPS*:* UPS delivery personnel carry a multipurpose electronic pad which is used not only to scan the shipment delivered by reading the bar code printed on it but also transmits the information captured by establishing a connection with the database machine. The information is transmitted to the collecting servers over the wireless connection established using existing cellular operator infrastructure

or by dialing using a fixed line connection. Essentially these pads have a built in modem and voice decoder that supports both voice and data communications. These pads possess memory sufficient enough to store 10 deliveries information and collated information is sent at once to the collecting databases. Data collected comprises the unique identity of shipment, address of delivery, name and signature of the person, delivered to.

UPS is not using satellites to track or deliver the information.

FEDEX: FedEx's newest data collection device for couriers incorporates a micro-radio for hands-free communication with a printer and mobile computer in the courier's delivery vehicle. It is known as PowerPad and devices also use Bluetooth wireless technology that allows FedEx couriers to communicate with each other within 30 feet of their vehicle. These devices relay the data using either cellular networks or satellite-based system. Customers can access package tracking and drop-off location data for various FedEx services via Web-enabled devices such as WAP phones, Personal Digital Assistants and pagers.

Proctor and Gamble: Company initiated a process to put in place a web-enabled alliance with partners for a consumer-driven supply chain. The idea is to take updates from retailers on customer demand i.e. create "demand triggers" that forecast the right amount of product mix needed. The software will also take into account the delivery schedule of raw materials and production cycles.

Aviall Inc: Aviall, Inc. is a leading solutions provider of aftermarket supply-chain management services for the aerospace, defense and marine industries. Aviall is using mobile technology in their supply chain management process in an effort to speed up the way its sales force tracks customers' product inventories. The need for real-time, accurate inventory data is prodding Aviall and other companies to turn to handheld devices for supply chain uses. Aviall Services Inc. has selected supply-chain planning and execution software from Xelus Inc., a core component in a real-time global network that will let Aviall forecast demand for replacement parts, plan for storage and warehousing of the parts, and manage the logistics of parts deliveries to its 17,000 customers.

Nicor Gas: Nicor Gas, a natural gas distribution company is using a radio frequency-based system using devices from TS-Tek Inc for supply chain management. The device beeps if inventory items are scanned improperly or placed in the wrong bin. The collected data is fed immediately into Nicor's back-office systems, ensuring that the company has current and valid information about its stock levels. Previously, it used to take two to three days to determine the status of a piece of inventory.

Hunt Corp: A distributor of office supplies also considered installing wireless technology within its supply chain operations. Their view is that Wireless devices could offer a faster and more reliable means of communications with customers

and business partners than hard-wired Internet or electronic data interchange methods.

Landstar: A transportation services company began wireless data access to an existing Web-based application in 2001. Nearly 9,000 independent drivers working with Landstar use a Wireless Application Protocol (WAP) phone to find available loads to carry, make bids on them, report their delivery status and check the balance on their Landstar debit cards, which are used to transfer payments for work.

Woolworth's UK: Company is using RFID, GPS and wireless handhelds to lower costs and reduce inventory levels. RFID tags on pallets allow items to be tracked as they move through the distribution center to the shipping area. Once the pallets are loaded on a truck, GPS is used to monitor the vehicle as it moves toward a Woolworth store. Upon delivery, the driver reads the RFID tags with a handheld scanner, and the store confirms that it has received the pallets it was supposed to receive.

McLane Co.: A logistics company has installed mobile computers with satellite and wireless communications systems in 1,050 trucks in its grocery store delivery fleet, transforming the vehicles into mobile information centers tied into its back-end systems. The McLane system, built around an onboard communications terminal and a rugged Symbol handheld computer running Palm OS, provide the company with a paperless process that manages all invoicing and delivery transactions, including capturing electronic signatures for proof of delivery. The system also manages dispatch operations, automate driver logs and provide McLane with the ability to perform remote diagnostics on the vehicle via satellite

Quick & Reilly Inc.: Quick & Reilly Inc., a financial consulting firm chose w-Trade wireless trading system software from w-Technologies Inc. This software lets brokerage customers receive quotes and trade securities on Wireless Application Protocol phones, Palm Inc.'s handhelds and pagers. W-Technologies Inc has also introduced applications based on its underlying Mobilero wireless application server software, geared toward the customer relationship management and logistics.

FedEx Corporation in Memphis is also using Mobilero-powered service that lets customers track packages and locate drop-off stations.

Ford's Real-Time Location Asset Tracking System: Ford initiated a wireless asset tracking system, called a real-time location system, at the Michigan Truck facility. That tracking system has reduced Ford's labor costs and produced other savings by, among other things, allowing the Michigan Truck facility to pin down the location of any vehicle on its lot to within 10 feet. The asset-tracking project was part of a broader program to improve the automaker's ability to follow a vehicle through the supply chain from the time a customer initiates an order until

delivery. The program's ultimate goals include providing information to customers about the status of ordered vehicles and reducing the company's order-to delivery time to 15 days from about 60 days.

Wal-Mart's Smart Wireless Warehousing and Replenishment Experiment: Wal-Mart's supply chain pivot processes are tracking its inventory in warehouses and stores and replenishing them quickly. It has recently piloted a radio-frequency identification (RFID) initiative for these activities.

Gillette: Gillette's system tracks its trucks through GPS locators and contents through RFID tags. It also alerts its suppliers about the real-time movement of its goods, giving them visibility and forecasting ability.

There are other successfully examples such as that of Real-Time Information Management at Eastman Chemical; Automatic toll and payment collection system of EZPass employing RFID system. The introduction of these technologies has revolutionized the operations of these companies.

Wireless devices and mobile business solutions have the power to make significant improvement in supply chain management. The key to leveraging wireless technology in the supply chain is a good understanding of the impact of wireless solutions on the supply chain. With them, the supply chain can transformed from a reactive, digitally enabled, linear process to a proactive supply web that acts much like a nervous system. In this web, wireless devices allow the supply chain to instantly sense requirements, problems, or changes throughout the network. This access to real-time information will enable faster decision-making and greater communication among parts of the supply chain.

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6.5.7 Glossary

Bent Pipe Arch   In a bent-pipe system the satellite is used to relay communication between the end-user equipment and a ground station that is part of the terrestrial infrastructure.

Link Margin   It is a qualitative measure indicating how much better than simply adequate a communication system is. It is the difference between 'Available Signal to Noise ratio' and 'Signal to Noise ratio required for BER of $1/10^{7}$' in dB.

Form factor   Form factor describes the size, configuration, or physical arrangement of a hardware object.

Line of Sight   Line of sight," as used in communications, means that both transmitting and receiving antennas must be within sight of each

other and unaffected by the curvature of the Earth for proper communications operation.

Duplex distance Duplex distance is the distance between the uplink and downlink frequencies.

WPAN   Wireless Personal Area Network address wireless networking of portable and mobile computing devices such as PCs, Personal Digital Assistants (PDAs), peripherals, cell phones, pagers, and consumer electronics; allowing these devices to communicate and interoperate with one another.

Q-factor   Also known as Quality factor, it specifies how well the resonating circuit absorbs power over its relatively narrow resonance band.

Inductive coupling It is a mean of conveying radio frequency energy via an oscillatory HF magnetic field*.*

ISM   Industrial, Scientific and Medical – 2.4 GHz frequency band

U-NII   Unlicensed National Information Infrastructure – 5 GHz frequency band

EIRP   Equivalent Isotropically Radiated Power represent total effective transmit power of the radio, including gains that the antenna provides and losses from the antenna cable.

Open loop   It is a mechanism in which transmitted power of the user equipment is controlled by the by the equipment itself, based on the observations made on the signal strength received from the base stations.

Closed loop   In this, power control parameters are provided by the network on observing the signal strength and quality levels received by the network. Open loop and closed loop power control together ensures the efficient power transmission by the user equipment.

DRX   Discontinuous Reception enables the mobiles to extend the battery life by powering off nonessential circuitry during brief periods when pages (or communications) are not expected to be received.

OBEX   OBEX is a session protocol and is also described as a binary HTTP protocol. It is optimized for ad-hoc wireless links and can

be used to exchange all kind of objects like files, pictures, calendar entries and business cards (vCard).

LEO   A Low Earth Orbit is any Earth orbit up to approximately 1,500 kilometers in altitude. An advantage of LEO satellites is the low delay in comparison to MEO and Geo-synchronous satellites.

MEO   An earth orbit in an altitude roughly midway between the earth and geosynchronous orbit. Satellite orbits between the altitudes of 1,500 and 6,500 kilometers (930 to 4040 miles) may be considered MEOs.

GEO   This orbit is directly above the equator, about 35,800 kilometers (22,300 miles) above the earth in space. When positioned in this orbit, a satellite appears to hover over the same spot on the earth because it is moving at a rate that matches the speed of the earth's rotation on its axis.

Ka Band   This refers to band of frequencies in the 18 to 31 GHz range that is available for global satellite use.

Ku Band   This refers to band of frequencies in the 10.9 to 17 GHz range that are used for fixed satellite service applications.

L-band   This refers to band of frequencies in the 0.5 to 2 GHz range that is used primarily for voice communications.

S-band   The portion of the electromagnetic spectrum allotted for transmission in the 2 to 4 GHz frequency range.

TDOA   Time Difference of Arrival: In this method, network uses its base stations to triangulate a fix on the handset, based the time of arrival of signals from the handset.

EOTD   Enhanced Observed Time Difference of Arrival: In this method, the handset calculates its position by triangulating signals from base stations or reports the triangulation measurements to the network this known as assisted mode, which then calculates its position.

WAP   Wireless application protocol is a global open standard for applications operating over wireless networks. WAP provides a uniform technology platform with consistent content formats for delivering Internet- and Intranet-based information and services to digital mobile phones and other wireless devices. It supports

Web browsing and related Web applications through a tailor-made interface for wireless units.

Enabling Logistics with Portable and Wireless Technology Study

AUTHORS

The Pennsylvania State University, University Park, PA 16802
School of Industrial Engineering
  Dr. Soundar Kumara
  Dr. N. Gautam
Pennsylvania Transportation Institute
  Dr. Zolton Rado
  Dr. Robert Gray
  Dr. Aylin Yener
School of Information Sciences & Technology
  Dr. Dave Hall
  Dr. Irene Petrick
Project Manager: Col. Barney Grimes, USMC (Ret)

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1   Executive Summary

1.1   Project Description and Focus

This study employs a three-pronged approach to identify potential wireless applications that extend and improve U.S. Marine Corps logistics. The three parallel efforts include (1) an assessment of the   Marine Corps Logistics Operational Architecture (OA) as it interfaces with the Global Combat Support System—Marine Corps (GCSS-MC); (2) a comprehensive study of private sector commercial wireless logistics applications; and (3) an assessment of current and emerging wireless technology solutions.

The challenge is to integrate these three efforts to identify the best features in the USMC logistics chain to enable with wireless technology. Our intent is to balance the potential for wireless applications with the unique USMC warfighting demands. See Figure 1.1.
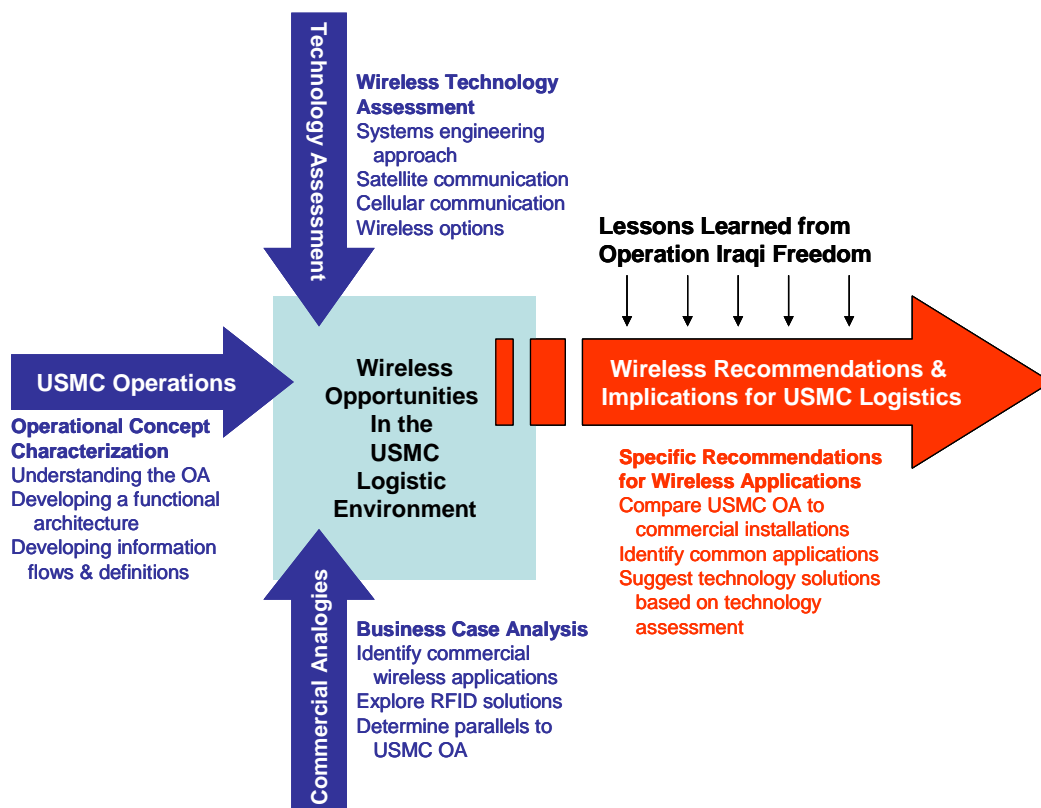
Figure 1.1: Three Penn State parallel efforts combine to support recommendations of wireless applications in USMC logistics

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In recent years, significant advances have been made (and are continuing to be made) in the technology associated with wireless communications. Advances in devices such as wireless sensors, portable computing devices, and local and wide band communications systems offer the USMC unprecedented opportunities to improve logistics activities in areas including:

- Automated detection and characterization of the state of USMC platforms and systems;
- Communication of system and human needs from the local point of service (POS) to regional and global arenas;
- Establishment of new supply chain information concepts and logistic situational awareness;
- Improved logistics and asset visibility based on improved (more precise) knowledge of what supplies and parts are needed and when they will be needed; and
- Transformation of current logistics planning to an accurate, predictive "preparation of the logistics battle space" concept analogous to current intelligent preparation of the battlefield planning.

Our recommendations should guide the USMC's future activities in several ways. First, our findings will identify the best near term and mid-term applications for USMC wireless, emphasizing technology solutions, implementation issues, and suggestions for further vendor exploration.

Specifically, our efforts will provide answers to the following five questions.

1. What technology is **BEST** suited to specific aspects of the USMC OA based on commercial applications, emerging technology assessment and anticipated USMC needs?

2. What technology is **NOT** recommended based on problems observed in commercial sector applications, soon-to-emerge technology alternatives, or unique USMC needs?

3. What are the implications for wireless transmission of data in USMC logistics and how might implementation issues be anticipated?

4. What follow-on USMC decisions can be anticipated based on our findings and recommendations?

5. What supporting information or studies might be needed to clarify USMC decisions with regard to wireless applications in USMC logistics?

1.2   Objectives

The utilization of portable computing and wireless communications provides an opportunity to significantly change and improve the logistics and operational readiness of the USMC.   The ability for individual platforms and individuals to provide information about equipment needs, anticipated failure conditions, current state of each weapon and support system will allow the USMC to become "leaner" and more effective.   Using the terminology of Secretary of Defense Rumsfeld, this will provide "more teeth and smaller tail" fighting force capability for the USMC.

The objective of this project is to identify, describe and quantify how portable wireless technology can be most effectively used in the USMC Logistics Operational Architecture. The research is bounded and guided by the following considerations.

- Focus on request management (RM), order management(OM), production management (PM), capacity management (CM) and the execution of these three areas;
- Assume a single order manager function with multiple request managers;
- Evaluate the impact of portable/wireless technology on logistics processes using the performance metrics described within the OA logistics scorecard;
- Commercial-off-the-shelf (COTS) technology must interface with current and future systems architecture as described within the OA;
- Focus on critical, high priority weapons systems, services and supplies;
- Portable-wireless technology solutions will comply with or function outside the radio-frequency controls dictated by current military policy;
- Balance battlefield management and warfighter safety with wireless enabled logistics applications; and
- Recommended solutions should be deployable with Marine Air Ground Task Forces and interface with GCSS-MC as it is currently envisioned.

1.3   Current Focus

The first two phases of this study focused on understanding the USMC Operational Architecture (OA), and assessing the private sector application of wireless in logistics and potential near term and emerging technology solutions. These activities have been reported in Interim Reports 1 (8 September 2003) and 2 (8 December 2003).

The current Interim Report focuses on our activities regarding comparing the USMC OA with commercial applications and on the efforts to build a proof-of-concept system to generate detailed technical specifications.   To make the comparison with commercial applications, the team has developed a set of

information system attributes that will guide comparisons and the formulation of recommendations in the coming months. This set of attributes is introduced in Section 1.5 and detailed in Section 2 of the current report.

1.4 Operational Concept and Vision

Elements of the Combat Service Support (CSS) are Supply, Maintenance, Transportation, General Engineering, Health Services, and Other Services. The logistics functionalities within the Operational Architecture that are significant to CSS are Request Management (RM), Order Management (OM), Procurement Management (PM) and Execution (E).

Figure 1.2 depicts the operational concept for wirelessly enabled logistics activities in the USMC. Here multiple request managers communicate either wirelessly or directly with a centrally located order management function. Order management then engages multiple supporting logistics activities to coordinate the acquisition and delivery of needed goods and services. Parallel communication channels of both direct and wireless ensure that battlefield requisition and supply is an on-going activity.

We have considered the deployment scenario represented in Figure 1.2 as our foundation for research, design and development of the wireless based infrastructure. Our vision of wirelessly enabled logistics continues to evolve through discussions with USMC, and information learned from Operation Iraqi Freedom.

We consider a Marine Expeditionary Force (MEF) that can execute concurrent sea based operations and sustained operations ashore. The supporting element (S1) would be the Force Service Support Group (FSSG). Within MEF, a self-sustainment for sixty days is available.

The MEF is assumed to contain supported units with RM capabilities, FSSG, and Sea-based vessels. The supported unit generates a request using electronic forms available on the portable devices. This information is wirelessly transmitted to the supporting units. The sources for the requested services/product are identified as follows:

- For services, the availability of personnel is determined by broadcasting messages (work orders, etc.) within the concerned unit.

- For products, availability within the sustainment-supporting unit is determined by means of automated identification (such as RFID tags etc.).
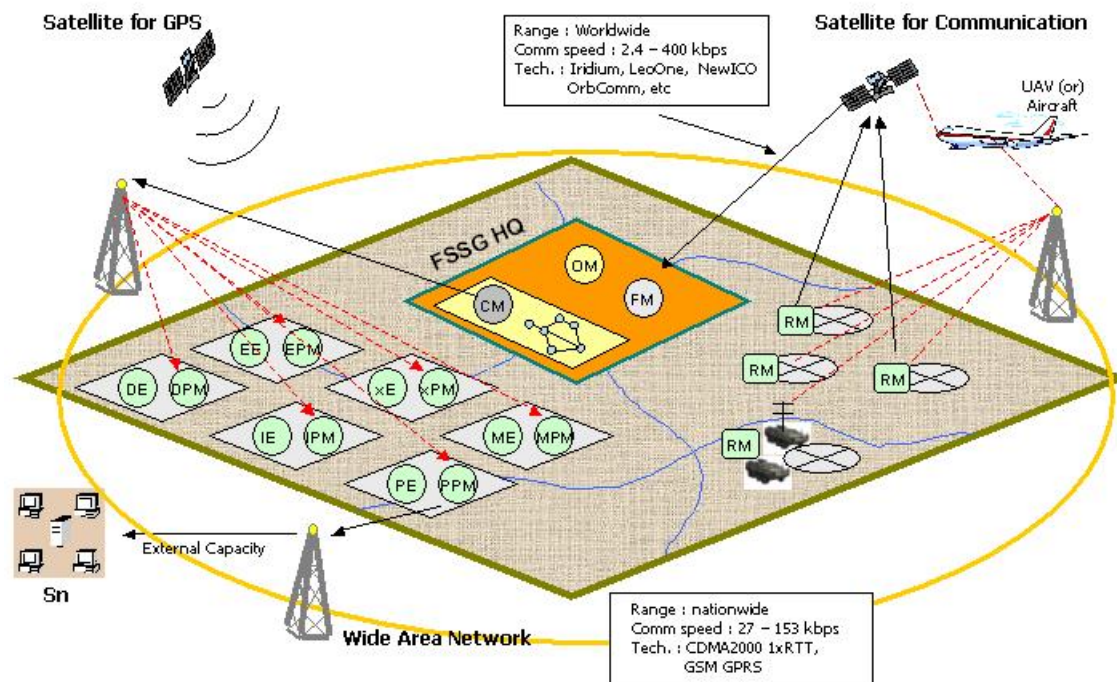
Figure 1.2: Envisioned Operational Concept

After identifying the services/products they are transported to the customer. The scheduling system needs to be aware of the availability and location of the transporting units with respect to the customer. The location information of the customer and transporting units in real time is captured using Global Positioning System (GPS) enabled devices that will continually transmit the location information to a centralized server. The timeliness of transmission depends upon the bandwidth availability. The candidate transport execution unit(s) is identified and routes are generated to assist the navigation. Geographical Information Systems (GIS) in combination with the sensor systems such as "smart dust" are used to generate routes. During transit, the contents within the transporting unit are traced which facilitates the commanding officer to reroute the shipment, in the event of contingencies. GPS and GIS will aid the transporting unit to obtain real time feedback for navigation and also to deliver the products. Upon arrival at the customer, the relevant RFID tags are scanned to generate an automated receipt that is used subsequently to update the inventory database.

1.5 Methodology to Compare USMC OA and Commercial Systems

A top down and bottom up approach inform our work. Figure 1.3 highlights this, thus guiding the further formulation of our research questions.
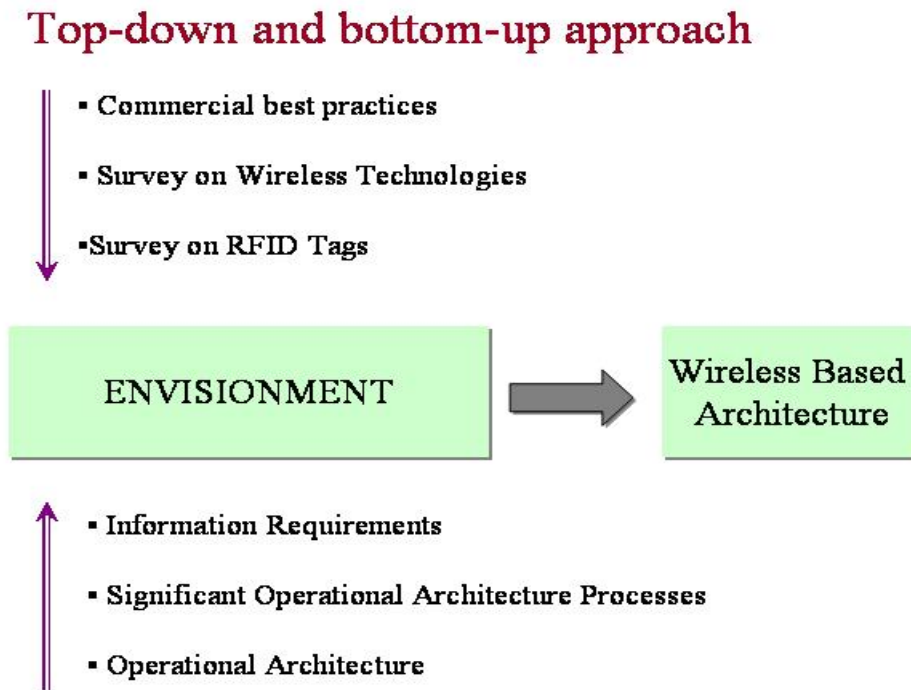
Figure 1.3: Top-down and bottom-up approach to develop recommendations

To compare commercial applications with the USMC OA, we must first develop a set of attributes to describe the typical logistics information support system. These attributes must begin at the top level to define overarching system attributes and will then provide the framework for us to define the USMC OA and then to define commercial activities with respect to this same set of attributes.

Table 1.1 highlights the approach we are taking. The attributes in the left-most column in Table 1.1 are further detailed in Section 2.0 of the current Interim Report.   Data detailing the USMC Concept will be derived from Section 3.0 and the supporting appendices of this report. Data for the commercial applications (the yellow portion of the table) will be garnered from information in Appendix 6.1 of IPR2 and will be extended through additional commercial application review and interviews with commercial vendors and users.

It should be noted that Table 1.1 indicates only one column for the USMC OA. This is for simplicity of presentation only. As described later in Section 3.0, the complexities of the USMC OA and the various use cases studied indicate that there may be more than one column to include for the USMC OA depending on the flow of information across various nodes and links in the system. Presently, there appear to be five possible USMC OA link analyses needed to complete Table 1.1:   (1) Supported Unit – Request Management; (2) Request Management – Order Management; (3) Order Management – Capacity Management; (4) Capacity Management to Production Management and (5) Production Management – Execution.   The final report will merge these two issues into a cohesive framework.

Once we have completed Table 1.1, the team will identify common elements between the USMC OA and commercial applications. Once these commonalities are identified, we will consider the commercial Off-the-Shelf products and technologies for possible adoption by USMC. Our deliberations will be refined through careful assessment of COTS solutions in comparison to the emerging wireless technology solutions and in consideration of stated DoD and USMC preferences for technology and communication solutions.

In addition, our recommendations for possible adoption will be further refined by careful consideration of the implications for wireless enabled logistics communication as they might impact the efficiency and the safety of a deployed USMC warfighter.

Table 1.1: Methodology to Compare USMC OA to commercial installations based on a standard set of information system attributes

ATTRIBUTES	USMC CONCEPT	FEDEX	GE	AMAZON	…….
Connectivity	Information from OA	Business case analysis & analogies			
Hierarchy					
Media for Communication					
Link Capacity					
Request Frequency					
Push/Pull					
Proximity					
Type of Tracking					
Tracking Level					
Environmental Conditions					
Item Time Criticality					
Safety & Security					
Item Value					
Criticality					
Operational Environment					
Detectability					
Item Availability					
Form of Communication					
Item Life					

1.6   Progress to Date against Task List

Six tasks are specified in this project:

Task 1:   Background Research & Review of OA Processes and Performance Measures
Task 2:   Market Research & Recommended Processes to be enabled
Task 3:   Identify key Data Elements 7 Information
Task 4:   Determine Unique Military Considerations
Task 5:   Determine Feasible Solutions
Task 6:   Determine Impact of Implementation

Table 1.2 summarizes our progress to date on these tasks as of 20 February 2004.

Table 1.2: Summary of Task Activities to Date

Task	Activities	Summary of Progress
1. Background Research & Review of OA Processes & Performance Measures	• Review OA Reference Materials and training • Compile and analyze previous studies	• Completed OA exploration • Completed literature search
2. Market Research & Recommended Processes to be Enabled	• Review commercial applications • Analyze use case scenarios • Review wireless technology options	• Conducted initial literature review of commercial wireless logistics applications focusing on RFID • Conducted interviews with commercial vendors • Developed expanded case studies of FedEx and UPS • Completed wireless technology assessment • On-going interviews with commercial vendors
3. Identify Key Data Elements & Information	• Determine quantity/quality /timeliness of information used at unit/end item level, MEB level, • And HQMC/SYSCOM /MCLC level • Consider data rates, transactions and bandwidth constraints	• Developed transaction models for OA processes. • Developed node-to-node data element tables • Developed initial data element model
4. Determine Unique Military Considerations	• Determine most likely communication channels (satellites, etc) • Identify unique constraints (e.g., timeliness, interception risk) • Evaluate OIF lessons learned • Consider DOD policies for RFID and other wireless applications	• Conducted interviews with USMC logistics personnel • On-going review of Operation Iraqi Freedom reports • On-going review of emergency DoD acquisition plans
5. Determine Feasible Solution	• Compare USMC OA and commercial practices • Identify common applications • Consider best practice and lessons learned in commercial sector • Refine wireless solutions for unique USMC applications	• Developed initial architecture for wireless support concepts • Developed attribute list for comparison of USMC OA and commercial applications • To be done: technology solution assessment and comparison to emerging technologies
6. Determine Impact of Implementation	• Interpret and correlate the results of tasks 2-5 • Identify wireless technology implications for USMC logistics activities • Suggest follow-on decisions • Identify required supporting information or studies	• To be done: development of prototype system to identify bottlenecks, implementation and data issues • To be done: On-going interviews with commercial users to determine possible problems with applications

1.7 Anticipated Future Work

In the coming months, the Penn State team will focus on populating Table 1.1 with the USMC OA and commercial applications. This is the next necessary step in our approach to identify specific COTS applications that might be suitable for request management, order management, production management, and the execution of all three. Once we have identified potential common needs and approaches, we will explore the technology implications to determine (1) how the technical solution compares to stated DoD and/or USMC communication preferences; (2) whether or not there are newly emerging technology solutions that might offer a longer-term solution; and (3) whether there are unique USMC battlefield or warfighter needs that might contraindicate a particular COTS solution.

In support of these activities, and to enhance our ability to anticipate technical and implementation issues, we will be developing a proof-of-concept wireless system to simulate logistics activities. This will provide needed details about communication rates, interface issues between possible COTS vendors and applications, while also guiding comparisons of performance between various COTS vendors. Figure 1.4 provides a conceptual view of an implementation prototype. Here, we have identified various software packages, interfaces, and communication mechanism that might fit together into an integrated wireless system.
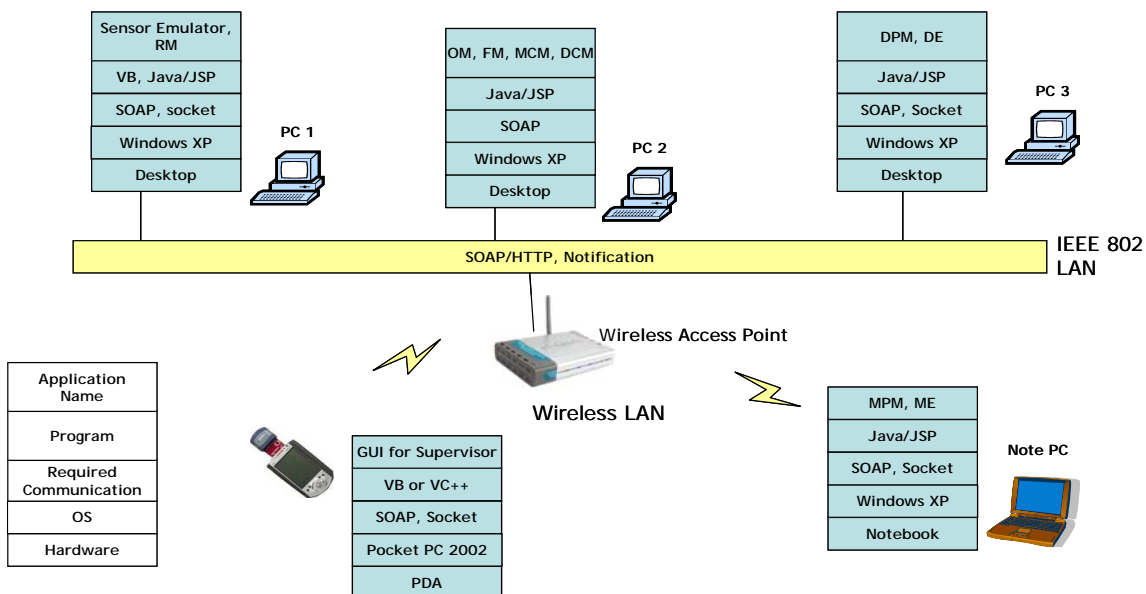
Figure 1.4: Conceptualization of proof-of-concept Implementation System

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2 Attributes to Compare USMC OA and Commercial Installations

The team has identified 19 high-level system attributes that might be useful to compare the USMC OA and commercial installations. The goal is to identify those commercial solutions that appear to have common elements to USMC OA needs. Once these COTS are identified, we can begin to answer several important questions: (1) What technology solutions are a good fit to existing and near term USMC plans for the OA? (2) What technology solutions should be considered for future implementation in the USMC OA? And (3) what technology solution should not be considered for the USMC OA based on unique features of the USMC logistics operations or the OA itself.

The attributes describe high-level system features and communication patterns. We anticipate that this list may grow after USMC input, and that it certainly will need refining as we begin the difficult task of matching the OA and commercial installations to its categories. Presently, Table 2.1 provides details about the attributes, our rationale for considering them, and examples of the types of options for completing the category.

Table 2.1: Attribute Description

Tentative Attribute List	Description & Rationale	Possible Options
Connectivity	The number of nodes that might need to connect has implications for throughput and bandwidth. It also may help determine prioritization of incoming/outgoing communications.	Many-to-many / Many-to-one / One-to-one
Hierarchy	Hierarchy might influence prioritization of communication and will also help determine the expected direction and location of communication nodes. It implies relationships between nodes.	Structured / unstructured Vertical / horizontal Centralized / decentralized / networked
Media for Communication	The mechanics of communication will influence technology options and choices, as well as packet size.	Text / voice / digital / image Encryption
Link Capacity	The characteristics of the node will influence the throughput, which in turn will influence the possible packet size and media choices for communicating.	Number of simultaneous connections, given bandwidth
Request Frequency	Some communication patterns can be predicted while others occur as the result of a need or occurrence. Request frequency indicates how often this type of communication can be expected	Frequently / infrequently /unique occurrence Number and complexity of communications per

	to occur.	unit time period _Needs refining after discussions with USMC staff_
Push/Pull	Information can be pushed (originating from the sender) or can be pulled (originating from the receiver).	Push / pull
Proximity	The geographic proximity of the communication nodes (sender and receiver) influences the technology solutions that might be useful. Implications of proximity include signal strength, tag type (if RFID), and mechanics of encryption. International proximity will require communication frequency considerations, as these are not standardized throughout the world.	Within plant / within inventory yard / within shipyard or dispatch yard Regional; national; international
Type of Tracking	This item is related to the flow of items throughout the logistics chain (as opposed to the flow of information). The type of tracking will be related to the nodes of communication.	Receiving / moving within fixed location / tracking across locations
Tracking Level	Another item-level attribute. Tracking level is the level of granularity desired in tracking individual pieces, cases, pallets, or larger shipments. It will have implications for the type and location of any inventory tracking devices.	Item level / pallet level / container level
Environmental Conditions	This is an item-level (or node level) attribute associated with the environment through which the item will move in the logistics chain. Water, dust, temperature and other environmental factors might influence tag choices. We also anticipate that the environmental conditions might influence choices for communication mechanics (impact of cloud cover on reception or use of solar power). Finally we anticipate that the environmental conditions in which the item (including a person) might be working will influence choices about the best human computer interface.	Normal / stable / extreme Temperature Humidity Weather (Cloud cover) Normal communication options (keyboard-based) / hands-free communication options
Item Time Criticality	How critical an item is depends on its uniqueness/risk and on its mission value. We will use USMC categories for this. We anticipate that critical items would have different tracking priorities than routine items. In addition, a time dimension might be added to the USMC categories to identify those items that are perishable.	Routine / bottleneck / leveraged / critical Perishable
Safety & Security	The type of item being tracked has implications for its safety and security requirements. Methods to track people would be potentially different than those to track tanks or routine parts. Methods to	Commodity / warfighter Useful to enemy / not-useful to enemy

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	track ammunition, computers or gasoline might be very different than those used to track spark plugs or paper products.	Options in this category still need refining after discussions with USMC staff
Item Value	High value items such as computers might be tracked very differently than commodity items. This attribute is related to Tracking Level.	High dollar value equipment and items / scarce items / commodity items
Criticality	This attribute ties in to the Item Time Criticality, but might also include broader strategic considerations. For example are tanks more critical (overall) than LAVs, are some types of weapons more important than others. In this case there might be subclasses within the Item Time Criticality categories.	Options in this category need refining after discussions with USMC staff Strategic implications of routine / bottleneck / leveraged / critical categories
Operational Environment	Even though the USMC OA should work in a similar way regardless of whether the information is flowing on the battlefield or in garrison, the operational environment will have implications for power, redundancy of systems, and other technology issues.	Battlefield / in-country distribution center / state-side distribution center / garrison
Detectability	Must an RFID or other tag is invisible to the eye. This attribute might be more important to the USMC, but there are some parallels in the commercial world.	Invisibility important / invisibility not important
Item availability	This is an item level attribute that relates to the tracking requirements, supplier pedigree and the predictability of the item's availability. Item Availability is related to criticality and Item Time Criticality, but should be separated from these to capture the predictable nature of the nodes of communication.	Stocked / single source / multiple source / made to order / engineered to order
Form of Communication	This is an information flow attribute. Information provision, especially if it can be predicted (maintenance manuals) can be remotely stored and accessed on an as needed basis, for example, in a one-way information pull method; information exchange and decision-making both imply less predictable node-to-node communication.	Information provision / information exchange / decision-making

An example of the way that this attribute list might be used to match OA processes to commercial applications can be seen with the Sears maintenance service. Sears delivers maintenance and repair services remotely using a truck that is equipped with several different types of communication channels.

Sears has equipped the trucks used by 10,000 service technicians with GPS 802.11 wireless LAN and packet data services supported by a five-antenna dome located on the trucks. The configuration is detailed in Figure 2.1 (which was included in Appendix 6.1 in IPR2). The five-antenna configuration includes:

1. An 802.11b wireless local area network
2. One antenna for traditional terrestrial packet data network, such as Mobiltext
3. One antenna for a more expensive satellite packet network;
4. An antenna dedicated to feeding the GPS signal to mapping software on technician laptops; and
5. A not yet activated antenna that will use a back feed channel on the GPS signal that will pass it to a transceiver in a small device on the technician's keychain. This is intended to pinpoint the technician's location.
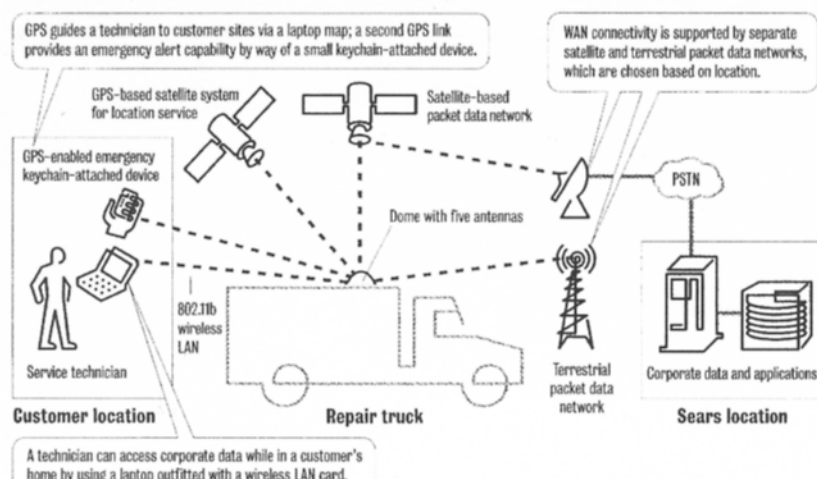
Figure 2.1: Sears Maintenance and Repair Services Offered Remotely

The Sears example actually covers several nodes in the USMC OA as will be described in Section 3.0. In general, it is an analogy to the use case for Maintenance at Customer also described in the next section. Not all of the information is available as of this IPR3 to complete the table, but when possible items are completed and questions are raised for further discovery.

Table 2.1 demonstrates the difficulty in assuming a single analogy to the USMC OA, and further demonstrates why the study team will consider multiple activities within the USMC OA as individual nodes. For example, the single attribute, "Connectivity," has several interpretations:

- Supported Unit (customer) to Request Manager (dispatcher), a many-to-one connectivity

- Request Manager/Order Manager/Capacity Manager/Production Manager done by dispatcher function, a one-to-one type of connectivity if all of these functions are indeed done in a single location by a single group and if item needed is in stock. For not in stock items, connectivity may be one to few or many, depending on how many suppliers are used for parts.
- Production Manager (dispatcher) to Execution (repair person), a one to many connectivity

Table 2.2: Sears Maintenance & Repair Attributes

Tentative Attribute List	Features of System (General features without taking node-to-node communication channels into account)	Possible Options
Connectivity	Over 10,000 trucks work nationwide to meet the maintenance and repair needs of Sears's customers. Communication channels are expected to be arranged in regions, and perhaps by store location (TBD through interviews).	Few dispatch locations (arranged by region and/or store) each to several trucks Similar to a nationally networked version of one-to-many
Hierarchy	Single dispatch locations requesting services from multiple trucks	Structured; vertical
Media for Communication	Multiple antennae are used to provide channels of communication	Text / voice / digital Encryption (TBD through interviews)
Link Capacity	TBD	TBD
Request Frequency	Frequent communication between dispatcher and remote repairperson; most of the communication is predictable; give the type of equipment maintenance being done. Specifics of this category will depend on interview information (TBD)	Frequently (with some unique occurrences, depending on repair needs) Number of communications per time period (TBD)
Push/Pull	Both push and pull. Push will be from the dispatcher to the repairperson for assignments; pull will be from the repairperson to a database for information, to a maintenance manual for information, with specific needs determined by unique equipment repair needs. Parts will be provided on-site if available or requested (pulled) from the store or regional warehouse	Push & pull
Proximity	Regional proximity, with communication between the dispatcher and the repair person; between the repair person and the inventory manager	Regional

Type of Tracking	The repair person is tracked;	Receiving / moving within fixed location / tracking
	Any supply items requested through the system will need to be tracked, probably within location, until the repair truck returns to base to restock;	
	Items that are not in stock will have to be tracked for receiving at the regional distribution center or store location	
Tracking Level	The repair person will be tracked at the individual level using GPS	Item level
	Individual items may be tracked on an as-used basis	
Environmental Conditions	Normal operating conditions anticipated. No extreme temperature or humidity conditions anticipated (TBD through interviews)	Normal environments
	Hands free communication might be desirable for trouble-shooting, but not essential.	Normal communication mechanics
Item Time Criticality	This attribute might be related to whether or not the service is under warranty (critical to achieve in the lowest time at the lowest cost to reduce Sears' costs) or is a customer expense. Time criticality will be related to the specific maintenance/repair service needed. Perishable items not anticipated.	Routine / bottleneck / leveraged (TBD in interviews)
Safety & Security	Repair person tracking does not have same implications as USMC warfighter tracking since targeting is not an issue	Not applicable
Item Value	Anticipated low to mid-range value items to be needed during repair.	Low to medium value anticipated relative to value of service
Criticality	No parallel to Strategic criticality	Not applicable
Operational Environment	Repair persons working in remote (off-site) locations	Similar to battlefield potentially, but without security issues
Detectability	Do not anticipate that invisibility of any RIFD or other tags will be important.	Not important
Item availability	Item level tracking for maintenance and repair. Do not anticipate made-to-order or engineered-to-order.	Stocked / single source / multiple source
Form of Communication	Information provided from dispatcher to repair person (order initiation); information exchanged; information requested by repairperson; some decision-making, but probably not in a real-time setting.	Information provision / information exchange

In completing Table 1.1, supporting documents such as that in Table 2.1 will need to be developed for various commercial applications. Populating Table

1.1 will require several iterations between the USMC OA use cases and between commercial analogies and business cases to refine the attributes further.

3 Operational Architecture and Systems Architecture Views

3.1 Functional Areas and USMC Use Cases

The operational architecture view captures the operational elements along with the associated tasks, and relevant information exchange requirements. The functional areas considered are: Supply (Order fulfillment) services, Return services, Maintenance services, Procurement services, Distribution services, Health services, Engineering services and Customer service. Each functional area along with its sub categories is shown in Figure 3.1.
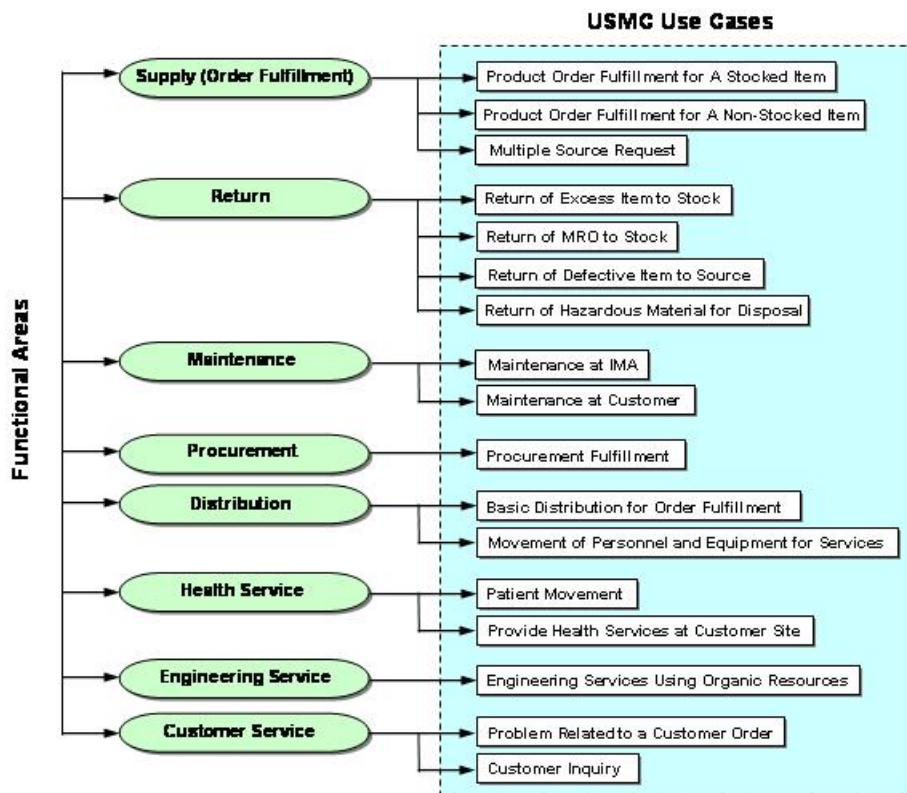
Figure 3.1: Functional Areas of OA and sub categories

Each sub category is represented in the form of use cases provided in the operational architecture CD. The use cases generated cover various elements - request management (RM), order management (OM), capacity management (CM), production management (PM) and execution (E). Any request made by the supported unit triggers its relevant use case and the corresponding nodes.

Based on the scenario shown in Figure 1.2, and on the recommendation of the sponsors, we consider the following assumption.

A single order management system and its management team manage all requests. This clearly shows man- to-one connectivity between RM and OM

In the interim report # 2, we have analyzed and studied the following uses cases:
- Order fulfillment
- Maintenance

We have shown the uses cases in the form of tables and information flow diagrams. Each table consists of the following details:
- Speaker – Process Originating a particular communication
- Listener – The destination module, where the information is received
- Performative – The action intended to be performed for a particular communication between two nodes [Kumara et al., 2003]
- Attributes –data elements that are transferred during communication
- Medium - the required mode of communication (for example voice, text, image, form etc)

The above terms were considered from the Knowledge Query Manipulation Language (KQML).

The information flow diagrams capture the sequential flow of information across the nodes for each use case. The tables in combination with the information flow diagrams clearly articulate the transactions within each use case.

In continuation to the above, we have extended our study to 17 use cases as shown Figure 3.1. In Table 3.1, Column 2 refers to the corresponding OA tables, Column 3 refers to the information flow diagrams and in the last column we specify the page number in this report where these details can be found.

Table 3.1: Completed Use Cases and Reference

Use Case Names	Tables	Information Flow Diagrams	Reference - (Pages)
Product Order Fulfillment for a Stocked Item	✓	✓	44 – 47
Product Order Fulfillment for a Non-Stocked Item	✓	✓	48 – 50
Multiple Source Request	✓	✓	51 – 52
Return of Excess Item to Stock	✓	✓	53 – 56
Return of MRO to Stock	✓	✓	57 – 62
Return of Defective Item to Source	✓	✓	63 - 66
Return of Hazardous material for disposal	✓	✓	67 – 70
Maintenance at IMA	✓	✓	71 – 75
Maintenance at Customer	✓	✓	76 – 79
Procurement fulfillment	✓	✓	80 – 81
Basic distribution for product order fulfillment	✓	✓	82 – 84
Movement of personnel and equipment for services one-way	✓	✓	85 – 87
Patient Movement	✓	✓	88 – 90
Provide health services at customer site	✓	✓	91 – 94
Engineering services using organic resources	✓	✓	95 – 98
Customer service - problem relating to a customer order	✓	✓	99 – 101
Customer service- customer inquiry	✓	✓	102 – 103

In order to identify possible technology solutions commercially used, we need to map the similarities between USMC operations and those prevalent in the commercial sector. Our analysis of the use cases resulted in identifying common information links, links 1 through 5 as shown in Table 3.2.   This is the first iteration to fill this table. We will be filling this table as we proceed further with this work.

Table 3.2: Attributes and OA Processes Relationship

Attributes	Link1 Supported Unit – RM	Link2 RM-OM	Link3 OM-CM	Link4 CM-PM	Link5 PM-E
Connectivity	Many-to-one	Many-to-one	One-to-one	One-to-one	One-to-many
Hierarchy	Structured, vertical	Structured, vertical	Structured, vertical	Structured, vertical	Structured, vertical
Media for communication	Text, Voice, Encryption	Text, Voice, Encryption	Text, Voice, Encryption, Digital	Text, Voice, Encryption, Digital	Text, Voice, Encryption, Image
Link capacity	(Request frequency) * (packet size for Media)				
Request frequency	**Must be provided**				
Information-Push /Pull	Push	Push	Push & Pull	Push	Push
Proximity					
Type of tracking	NA	NA	Moving within fixed location	Moving within fixed location	Moving within fixed location
Tracking level	NA	NA	Pallet Level	Pallet Level	Item Level
Environmental Conditions	-------				
Item time criticality					
Safety & security					
Item value					
Criticality	--------				
Operational Environment	Deployed /Garrison	Deployed /Garrison	Deployed /Garrison	Deployed /Garrison	Deployed /Garrison
Detectability					
Item availability					
Form of communication					
Item life					

3.2   Motivation

Most often high-level system architecture descriptions are viewed by many as a non-detailed version of the architecture as higher level is misinterpreted as lacking in depth. These descriptions tend to be more subjective, hand waving and impossible to implement. However one can generate a detailed version of the higher-level abstraction. In order to accomplish this we need a rationale and scientific basis. We therefore, analyzed many use cases to develop a clear understanding of the related OA processes and the ensuing information flows. The tables and information flow diagrams help to compute the following requirements:

- Connectivity
- Range of communication
- Response time
- Link capacity within the wireless network
- Medium of communication (Text, Voice, Image and Digital)

Certain processes captured within the information flow diagrams can be fully or partially matched with processes in the commercial sectors such as FEDEX, UPS, etc. Once this is accomplished, the technologies used by these sectors can be considered as a candidate for implementation within USMC OA.

The tables and information flow diagrams (Appendix 5.1) help in understanding the operational architecture. These can be used for educating the teams that use/develop the wireless architecture.

Information flow diagrams generated can be combined to develop an unified view of the transactions that take place between the nodes as shown in Figure 3.2. This will form the foundation for developing the systems architecture view. Each system would be a single node or a cluster of nodes. The capabilities and requirements for a system would be same as the nodes that it represents. For instance, the request management system would have the capabilities identified for the RM node across all the use cases. Thus the tables and the information flow   diagrams   will   be   used   to   develop   the   Systems   view.
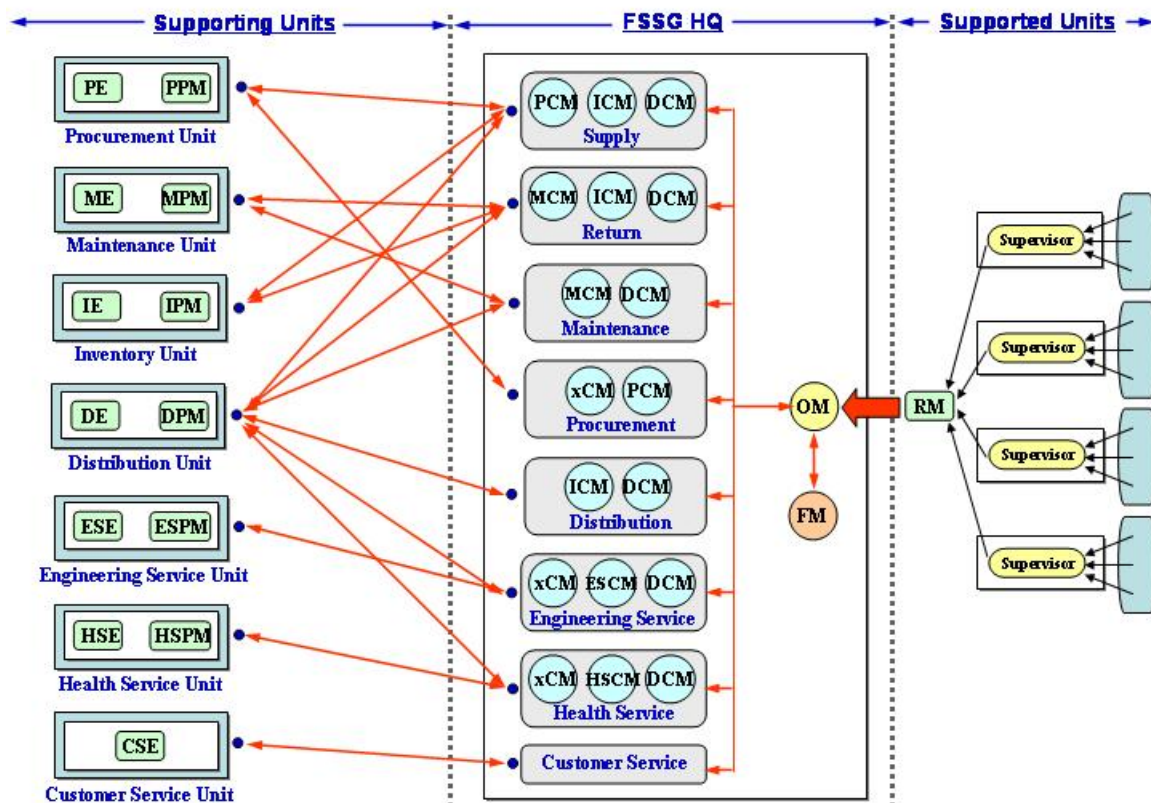
Figure 3.2: Unified view of the transactions between various OA processes

3.3 Scope

To generate a unified view as shown in Figures 3.2, we have considered requests of various types from the supported units to trigger the OM system. This unified view will help us to identify the common nodes that are triggered and their relevant requirements.   By coordinating with CM module, the OM system supports all planning activities.   The PM and E modules are assumed to be distributed geographically.   Hence, we consider a centralized control and distributed execution.
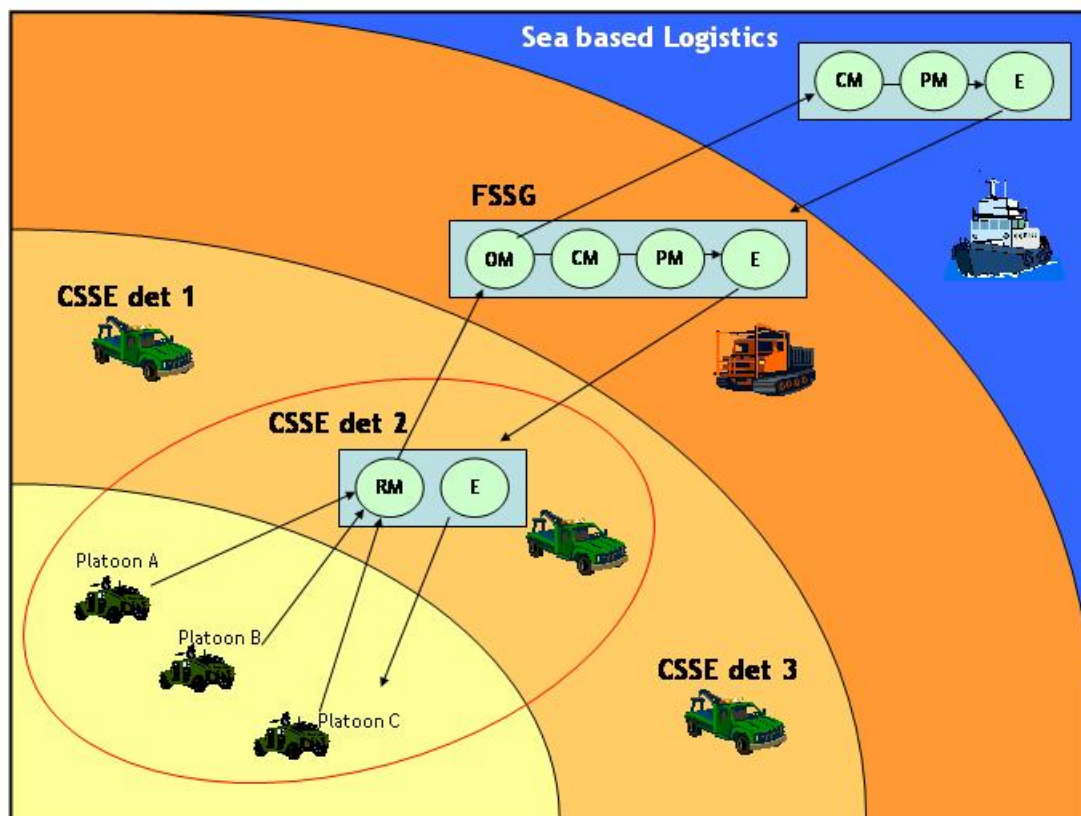
Figure 3.3: OA processes with relevance to the USMC organizations

Figure 3.3 shows the unified view of all the OA processes with relevance to the USMC organizations. This figure shows three significant segments within the USMC hierarchy. They are:

- Supported unit (a group of platoons supported by a Combat Service Support Element detachment (CSSE det))
- Force Service Support Group (FSSG) (centralized support service group)
- Sea based logistics

Supported unit has RM process and internally sourcing execution process. FSSG has OM, CM, PM and E. Sea-based logistics is responsible for managing inventory at a large scale and replenishing the requirements at FSSG.

The granularity of Figure 3.3 can be improved by considering a specific instance such as "a request for maintenance". This is shown with its different levels in Figure 3.4. The RM segment is common across all use cases, but differs at the FSSG level as shown. The OM for this instance triggers the maintenance capacity management module and distribution capacity management module. This in turn triggers its relevant production management module and execution module.
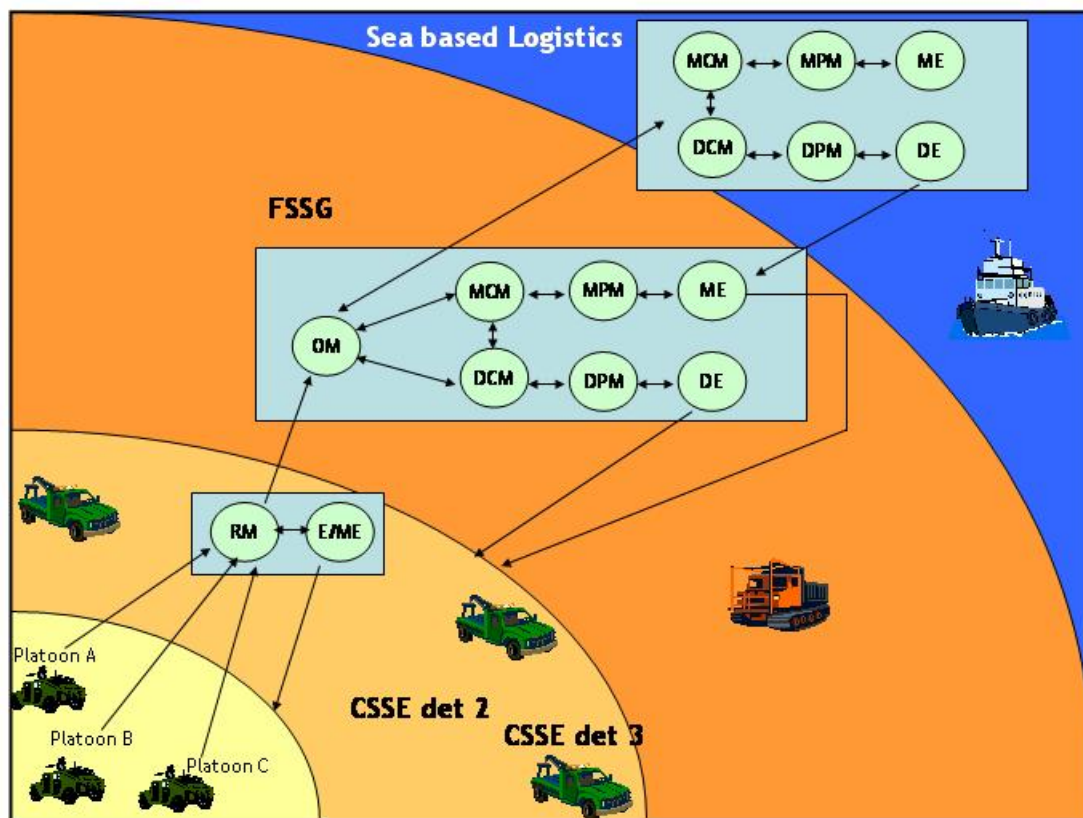
Figure 3.4: Instance for OA processes between the USMC organizations

3.4 Systems Architecture View

The systems architecture view describes various subsystems considered and the connections among them. The systems architecture view may be used for many purposes, including, for example, making investment decisions concerning cost-effective ways to satisfy operational requirements, and evaluating interoperability improvements. A systems architecture view addresses specific technologies and "systems." These technologies can be existing, emerging, planned, or conceptual, depending on the purpose that the architecture effort is trying to facilitate (e.g., reflection of the "as-is" state, transition to a "to-be" state, or analysis of future investment strategies).
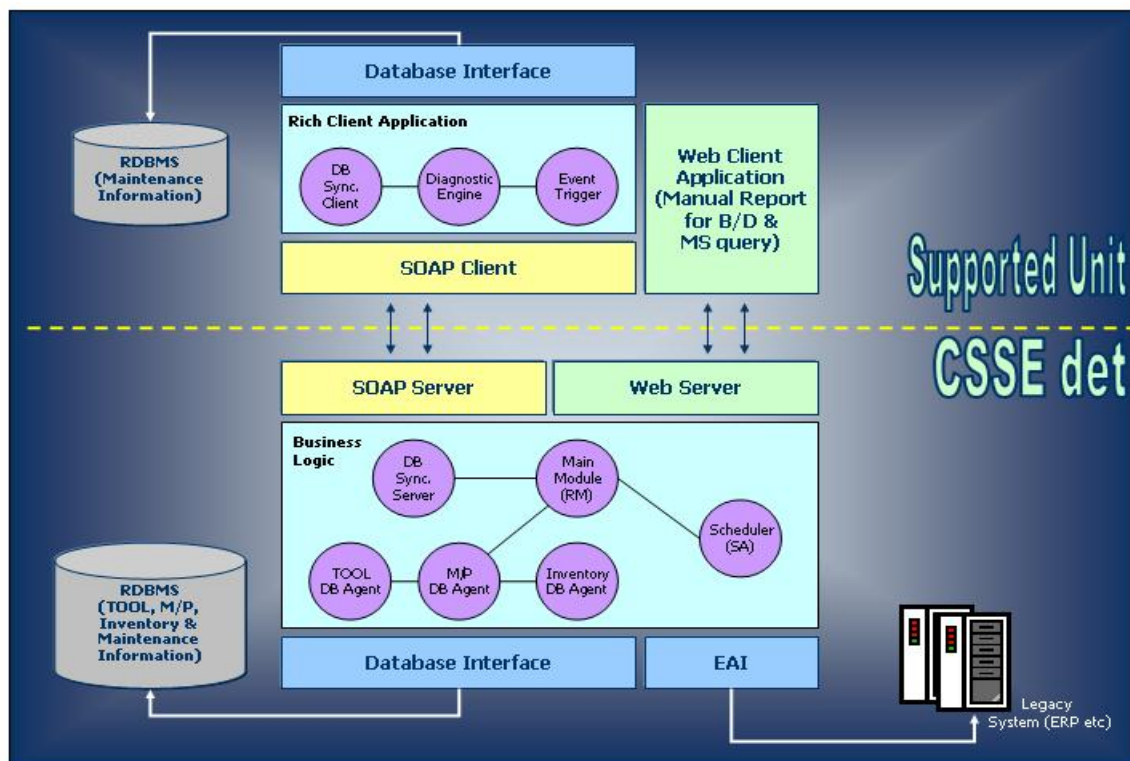
Figure 3.5: Systems view for Supported Unit and CSSE det
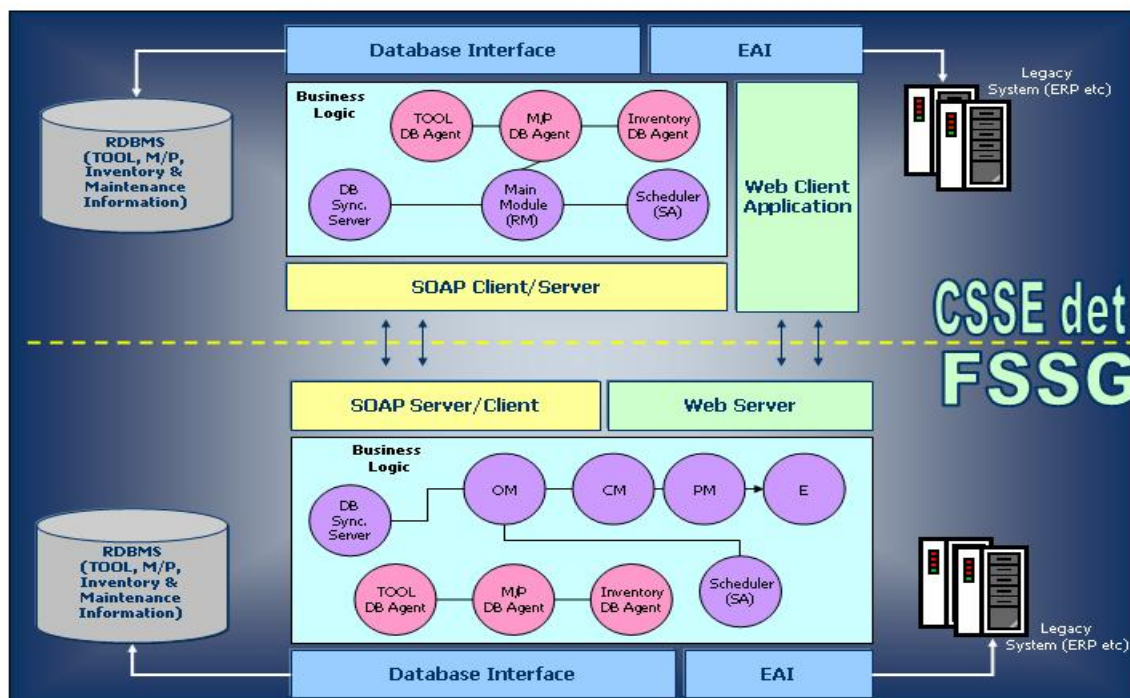
Figure 3.6: Systems view for CSSE det and FSSG

Figures 3.5 and 3.6 show the system details. Figure 3.5 shows the link between the supported units and the CSSE det and Figure 3.6 shows the link between the CSSE det and FSSG.

The component walkthrough for the particular system is as follows. It helps to investigate responsibilities, relationships and collaborations among the components.

Rich client application: A rich client application has a non-HTML (Hyper text markup language) user interface, for example a Swing client developed in Java. Because each end user works with a separate application instance, there usually is a one-to-one relationship between the user and a server.

It includes three modules
- Diagnostic Engine
- Database Synchronization Client
- Event Trigger

Web client application: A Web client application provides a thin, HTML-centric user interface. The presentation logic resides on the server, for example Java; it is typically implemented as a set of servlets and Java Server Page's (JSP) organized according to the Model View Controller (MVC) pattern. Many end users are served by the MVC implementation simultaneously. Therefore, a many-to-one relationship between the end user and the server exists.

Simple Object Access Protocol (SOAP) client: The client side SOAP runtime offers a generic, call-oriented Java SOAP Application Program Interface (API), an encoding subsystem and a transport subsystem. It uses the Hyper Text Transfer Protocol (HTTP) client to connect to and communicate with the service provider.

Web server: A computer that stores Web documents and makes them available to the rest of the world. A server may be dedicated, meaning its sole purpose is to be a Web server, or non-dedicated, meaning it can be used for basic computing in addition to acting as a server.

SOAP server: The SOAP server provides document and Remote Procedure Call (RPC) style transport endpoints, implemented as one or more servlets. At a minimum, it consists of a deployment configuration and an encoding subsystem as well as a set of utilities.

Business Logic: It includes the following modules:
- Database synchronization server
- Maintenance Scheduler
- Tool DB agent
- Manpower DB agent

- Inventory DB agent
- OA processes

Database Interface: It is defined as a set of methods, variables and conventions that provide a consistent database interface independent of the actual database being used.

Enterprise Application Integration: A central service through which other applications communicate. Its primary goals are to communicate changes in the data between applications (sharing or synchronizing data), and to invoke the business logic or services of an application from other applications (remote invocation).

Relational Database Management System (RDBMS): A computer program designed to store and retrieve shared data. In a relational system, data is stored in tables consisting of one or more rows, each containing the same set of columns. For example, Oracle is a relational database management system. Other types of database systems are called hierarchical or network database systems.

Agents: The business logic specifies the interaction between different software agents. Owing to the strict hierarchy of communication and processing, software agents are represented as Masters and Slaves. The master agent at each level corresponds to the OA processes such as request manager, order manager, capacity manager, production manager, and execution manager. The master agent through the communication server exchanges relevant information between the organizations. It is also responsible for receiving requests, parsing data, and distributing to its slave agents. The slave agents receive instructions from their master and respond according. In the instance shown, the master request management agent receives the maintenance request identifies specific attributes such as requirement for tool, inventory (part), and manpower. The data elements are transferred to the tool DB agent, inventory DB agent and manpower DB agent respectively. Subsequently, each of these slave agents queries the database and checks for availability. It is also responsible for dynamically updating the database.

3.4.1 Systems architecture view - details

Figures 3.6 and 3.7 represent our systems view of the implementation of OA. In specific, we focus on maintenance. The details are as follows:

- The maintenance requirement is either detected by the diagnostic engine within the end item or manually submitted through the web client application.

- The diagnostic engine upon detecting an anomaly transfers the information to the event trigger. This automatically generates a request.
- The request is sent through the SOAP client to the SOAP server and then to the main RM module. Alternatively, the manually submitted request is sent through the web server to the main RM module.
- The RM module parses the information and transfers specific requirements related to tools, manpower and inventory to the relevant slave agents.
- The slave agents query the database through the database interface and obtain availability information.
- Depending on the availability the maintenance scheduler module is directed to generate the optimal work schedule.
- If unavailable, the SOAP Client/Server at the CSSE det submits/forwards the request to the SOAP server at FSSG.
- Alternatively, the request can be manually forwarded to the FSSG through the web server.
- The main OM module receives the forward request.
- The OM module triggers the respective CM (maintenance CM) to check availability of resources. Simultaneously, the OM module checks with DCM for availability of transportation resources.
- After receiving the response from MCM and DCM, the resources are reserved and scheduler generates the work schedule for both MPM and DPM.
- MPM and DPM modules identify the resources for execution and assign the work orders to DE and ME.

4 Wireless Technology Evolutions

Wireless technology will play an integral role for the future success of the USMC warfighter. It has become clear to us over the course of the project that a number of scenarios exist where providing reliable wireless connectivity is likely to increase efficiency, provided the communication technology is secure, reliable and available under a variety of conditions.

Wireless devices and mobile business solutions have the power to make significant improvement in supply chain management and fleet management. The key to leveraging wireless technology in these fields is a good understanding of the impact of wireless solutions. With wireless devices and tracking mechanisms, the supply chain can be transformed from a reactive, digitally enabled, linear process to a proactive supply web that acts much like a nervous system. In this network, wireless devices allow the supply chain to instantly sense requirements, problems, or changes throughout the network. This access to real-time information will enable faster decision-making and greater communication among parts of the supply chain.

In section 4.1, our work scope for the next interim report is discussed. Section 4.2 is a first cut technical attribute matrix pertaining to wireless technology system issues, and Section 4.3 is a continuation from previous interim reports regarding best business practices of enabling wireless technologies.

4.1 Work scope for next interim report

To date, a comprehensive technical survey of mainstream commercially available wireless technologies has been performed (See interim report, IR #2). Our findings indicate that an array of technologies are available (e.g. satellite, 3G cellular, WLAN, RFID, etc.), and that the currently available technologies are likely to fulfill various quality of service (QoS) requirements for garrison, but importantly, during expeditionary missions. When possible, we will also integrate enabling wireless best commercial business practice researched and listed in the previous and current interim report.

Because we now have a better understanding and mapping of the operational architecture (OA), and consequently the specific needs of the USMC, the remainder of the project schedule will begin by making recommendations for the "best-fit" commercial wireless technology. A scorecard will be used to help maximize the benefits of wireless connectivity. Our plan for the remainder of the project is to come up with specific recommendations consistent with the needs of the different links described by table 3.2 of in this report.   In other words, in order to reliably meet the overall project outcome, we believe that our main aim for the remainder of the project should be to match our wireless technology and best

business practice findings with the OA model developed and presented in this interim report (IR #3).

Specifically we plan to determine the best technology out of possible candidate wireless technologies (short and medium range: satellite, RFID, WLAN such as 802.11g, 3G cellular, etc.) to be used in: Link 1 (Unit-RM), Link 2 (RM-OM), Link 3 (OM-CM), Link 4 (CM-PM) and Link 5 (PM-E).

4.2   Wireless Attributes

The attribute list in section 4.2 was a team effort to list quality or unique characteristics of wireless technology. The attributes in Table 4.1 are by no means complete, but are thought to cover both a broad yet critical mass of issues pertaining to wireless technology for USMC usage.

Table 4.1: Technical Matrix

Attribute	Options	Rationale
Reliability		Any wireless system can be severely handicapped unless it is reasonably sure that messages will be reliably conveyed. The military environment presents harsh challenges: interference from natural and man-made sources scuttle transmissions, propagation vagaries like signal fading and multipath occurrences complicate broadcasts, and shadowing from buildings and undulations in terrain can adversely affect message delivery. Packetizing data into smaller chunks provide efficient means, screen transmission errors and undertake very economical and cost-effective retransmissions if necessary. Different technologies under different circumstances may require multiple broadcasts (transmissions/re-transmission) to deliver clean data. Depending on the equipment basics and the environment, different technologies will prove to be an inefficient carrier of information. For any wireless technology to be worthy of sincere consideration, it must have a proven track record for providing a robust radio channel that can swiftly and surely carry mobile communications. Overall, reliability is quite a critical design issue.

Coverage		Newer wireless technologies, even though mostly serve only metropolitan areas, were designed with wireless infrastructures covering larger and larger geographical areas with less required equipment, thus saving on the equipment and deployment cost. Discussions with military representatives have led to the opinion that scaleable range communications are at least as vital to the workings of OA as other metrics. The requirement of coverage at different geographical scales is important, and those technologies that offer seamless reception throughout wide ranges will be noted.
Transmission Speeds / Data rates/Adequate functionality		Figures cited by wireless technologies regarding the transmission data rates supported can be misleading. Implemented coding, error correction and data re-transmission methods limits the overall data capacity available in a wireless channel/system. The transmission speeds are often less important than reliable figures on a network's throughput: the amount of message-specific data that reaches recipients in a given period of time. In some cases technologies offering fast transmission speeds may also provide fast throughput as well. However, evaluations should not only rely on transmission speeds alone. Transmission speed and throughput information are critical because they directly affect the efficiency of wireless communications systems.
Network Throughput		The network's data transfer characteristics are very important measuring and evaluation metrics since it also determine communication airtime costs. Technologies like cellular networks, determine costs based on the length of transmission. High transmission speeds and high throughput can bring financial savings through reduced airtime charges. Systems that use packet-data technology mostly accrue costs according to the amount of data transmitted. A number of mobile technologies employ store-and-forward architecture. These systems commonly do not have enough radio bandwidth and service capacity to instantaneously meet all messaging demands. These networks can delay communications for seconds, minutes, and sometimes even hours. These kinds of services usually offer much cheaper equipment and airtime costs.

Equipment and Airtime Costs		The critical value of equipment and airtime charges is obvious. Through recent developments and technological advancements more and more wireless technologies are cheaper to employ than traditional wired networks. Wireless communications in general for a long period of time will carry a premium cost. Heightened competition in the marketplace is giving customers increasing service options and acting to drive down the cost of transceivers (transmitters/receivers) and wireless airtime.
Scalability		Once installed, set up and working, is the system able to increase load, without loss of performance? Was the system designed so that it can be re-scaled in a simple straightforward manner by maintenance personnel? If so, how does the scalability take place (use of plug and play modules or something else), what is the upper limit value of performance scalability. For example, how many channels or how many end users can simultaneous use the communication channels at 100% of data transmission usage?
Encryption		Is the system backwards compatible with existing military encryption? How is the data being transmitted safeguarded? What type of encryption is being used, if any. What happens if the communication equipment is stolen or lost? Can the equipment be de-programmed remotely or can the enemy backwards engineer the device and solve the encryption secrets?
Authentication		This is a step before encryption. It prevents unlawful user from gaining access to transmission medium, thereby sabotaging the whole purpose of clandestine information transmission. This is more critical in military considering the fact that enemy spy always trying to crack the information

Frequency allocation		All over the world, the whole frequency spectrum has been divided very carefully into a number of bands, designated for the development and operation of various technologies. Information being sent in space is generally transmitted and received at specific frequencies and at specific power levels. The transmissions of data also takes up a certain amount (or bandwidth) of nearby frequency, too. The frequency chosen for a given wireless transmission is also associated with the size of antenna needed to send and receive data at that particular frequency and often relates to the transmission distance (how far one may send/receive) the data. The point of this attribute is to ensure the correct frequency is chosen in one's design and that the frequency is available for use (in other words, someone else is not already using the frequency).
Compatibility with other wireless systems/Conformance to Specifications		Compatibility with other systems or compliance with specifications is important to help assure seamless data transmission, reduce duplication of effort and save overall system costs. Generally each system has a specific data transmission standard, electrical interface characteristics and data protocol.
Support for voice and data and video		Generally, transmission of information implies sending data, voice or video information. Depending on the user needs and system requirements, each wireless device or wireless technology can be optimized to meet the data, voice and video needs of the user; however to date, not exclusive to cost.
Bandwidth		The greater the bandwidth of a wireless system, the more information that can be sent in a given amount of time. Transmission of digital voice data generally takes up more bandwidth than text-only data; digital video requires even more bandwidth than digital voice transmissions. However the bandwidth of wireless systems is not infinite and hence each wireless system built to date has a bandwidth limit. Also, given the range of wireless technologies, it is not possible to allocate large amounts of bandwidth to any technology or system without the possibility of inducing interference.

Power requirements		
		Power requirements are generally stated in units of Watts, but quite often, each system will be specified to operate in a range of voltages with waveform considerations (AC or DC, or both). Power requirements are often correlated with the overall mission time the system is needed to operate with full-power on and stand-by power requirements.
Susceptibility to interference		Each communication device must be specified and tested for the following interference types: conductivity, susceptibility and radiated emissions. Conductivity tests the units ability to handle induced noise being power-supplied; susceptibility is the ability of the unit to handle radiated emissions from neighboring equipment or other interference signals from the outside world; radiated emissions is that quantified amount of power which your system emits as interference either nearby or far.
Maintainability		Often overlooked or last to be completed are maintainability and system logistics needs. What levels of maintenance are needed? What is the Mean Time to Repair? What training or aptitude skills are necessary by the warfighter to maintain the system? What parts will be repaired at depot or disposed when found to be unserviceable?

4.3   Additional business practices of implementing wireless solutions in tracking and inventory management

This section is a continuation of previous interim report research regarding best commercial practices of companies using wireless technologies for fleet monitoring, positioning or enhanced supply chain management.

A. UPS

UPS delivery personnel carry a multipurpose electronic pad which is used not only to scan the shipment delivered by reading the bar code printed on it but also transmits the information captured by establishing a connection with the database machine. The information is transmitted to the collecting servers over the wireless connection established using existing cellular operator infrastructure

or by dialing using a fixed line connection. Essentially these pads have a built in modem and voice decoder that supports both voice and data communications. These pads possess memory sufficient enough to store 10 deliveries information and collated information is sent at once to the collecting databases. Data collected comprises the unique identity of shipment, address of delivery, name and signature of the person, delivered to. UPS is not using satellites to track or deliver the information of the shipments.

B.   FedEx

FedEx's newest data collection device for couriers incorporates a micro-radio for hands-free communication with a printer and mobile computer in the courier's delivery vehicle. These devices, known as PowerPad also use Bluetooth wireless technology that allows FedEx couriers to communicate with each other within 30 feet of their vehicle. Once the data has been collected, these devices relay the data using either cellular networks or satellite-based system to the backhaul server. Customers can access package tracking and drop-off location data for various FedEx services via Web-enabled devices such as WAP phones, Personal Digital Assistants and pagers. Note that shipments are not tracked in the last mile of their delivery.

C. Proctor and Gamble

Company has initiated a process to put in place a web-enabled alliance with partners for a consumer-driven supply chain. The idea is to take updates from retailers on customer demand i.e. create "demand triggers" that forecast the right amount of product mix needed. The software solution will also take into account the delivery schedule of raw materials and production cycles. P & G has teamed up with Microsoft for that purpose.

In this solution, Microsoft has delivered a set of Microsoft BizTalk Server 2000 adapters that enable connection to the various point-of-sale systems used by grocery, drug and mass merchant retailers to collect near-real-time transaction data. The data is aggregated and transmitted for processing by a set of intelligent algorithms that identify potential out-of-stock items on a store-by-store basis. The detected out-of-stock information is transmitted back to store personnel using customized content rules. This approach offers significant flexibility by enabling notification via wireless communication devices, Pocket PC-based devices or existing retailer mediums.

Real time data collection is targeted to be collected using RFID tags employing Electronic Product Code (EPC) proposed by Auto Id centre. P & G is working with Walmart for identifying every pallet and case with RFID tags bearing EPC. The whole process would enable all segments of supply chain to share the information over the network using a Web portal or a proprietary network.

Procter & Gamble expects a 25% improvement in inventory and a 10% savings in overall supply-chain costs resulting from RFID-related efficiency gains.

D. Aviall Inc.

Aviall, Inc. is a leading solutions provider of supply-chain management services for the aerospace, defense and marine industries. Aviall is using mobile technology in their supply chain management process in an effort to speed up the way its sales force tracks customers' product inventories. The need for real-time, accurate inventory data is prompting Aviall to turn to handheld devices for supply chain uses. Aviall Services Inc. has selected supply-chain planning and execution software from Xelus Inc., a core component in a real-time global network that will let Aviall forecast demand for replacement parts, plan for storage and warehousing of the parts, and manage the logistics of parts deliveries to its 17,000 customers.

E. Nicor Gas

Nicor Gas, a natural gas distribution company is using a radio frequency-based system with devices from TS-Tek Inc for supply chain management. The device beeps if inventory items are scanned improperly or placed in the wrong bin. The collected data is fed immediately to Nicor's back-office systems, ensuring that the company has current and valid information about its stock levels. The solution has brought down the tracking and collection of information (determining the status of a piece of inventory) from two to three days to on the spot.

F. Hunt Corp

A distributor of office supplies also considered installing wireless technology within its supply chain operations. Their view is that Wireless devices could offer a faster and more reliable means of communications with customers and business partners than hard-wired Internet or electronic data interchange methods.

G. Landstar

Landstar is a transportation services company without owning a single truck, thereby managing their services by bringing together a network of around 5000 truck owners for shipping and distribution. Landstar began wireless data access to an existing Web-based application in November 2001. Nearly 9,000 independent drivers working with Landstar use a Wireless Application Protocol (WAP) phone to find available loads to carry, make bids on them, report their delivery status and check the balance on their Landstar debit cards, which are used to transfer payments for work. Lately, Landstar has signed SkyBitz Global

Locating System for satellite based communications and tracking services for transportation equipments. This helps Landstar in providing the customer with real time information about the consignments.

H. Woolworths, UK

Company is using RFID, GPS and wireless handhelds to lower costs and reduce inventory levels. RFID tags on totes, pallets allow items to be tracked as they move through the distribution center to the shipping area. Once the pallets are loaded on a truck, GPS is used to monitor the vehicle as it moves toward a Woolworth store. Upon delivery, the RFID tags are read again with a scanner, and the store confirms that it has received the pallets it was supposed to receive. This integrated tracking approach has brought product visibility in their inventory management chain, resulting in increased sales, better load control, improved fleet management and reduced theft.

Woolworths is working with Integrated Product Intelligence (IPI) to integrate fixed and mobile RFID data collection into existing systems within their distribution network. They are able to track and precisely locate distribution assets and their contents through the supply chain from the point of assembly to the point of delivery. The system automatically provides an audit trail of movements, locations and times, and enables investigation of security breaches. The same data is a valuable source of information to enable Distribution Management to improve business processes.

I. McLane Co.

A logistics company has installed mobile computers with satellite and wireless communications systems in 1,050 trucks in its grocery store delivery fleet, transforming the vehicles into mobile information centers tied into its back-end systems. The McLane system, built around an onboard communications terminal and a rugged Symbol handheld computer running Palm OS, provide the company with a paperless process that manages all invoicing and delivery transactions, including capturing electronic signatures for proof of delivery. The system also manages dispatch operations, automate driver logs and provide McLane with the ability to perform remote diagnostics on the vehicle via satellite.

J. Quick & Reilly Inc.

Quick & Reilly Inc., a financial consulting firm chose w-Trade wireless trading system software from w-Technologies Inc. This software lets brokerage customers receive quotes and trade securities on Wireless Application Protocol phones, Palm Inc.'s handhelds and pagers. W-Technologies Inc has also introduced applications based on its underlying Mobilero wireless application server software, geared toward the customer relationship management and logistics.

FedEx Corporation in Memphis is also using Mobilero-powered service that lets customers track packages and locate drop-off stations.

K. Ford Motor Company

Ford has installed a wireless asset tracking system, called a real-time location system (RTLS) at several of its plants throughout North America and Europe. They have implemented a system from WhereNet Corp., a wireless supply chain visibility solutions provider. It is driven by wireless tags, fixed position antennas, and Web-enabled software. This industrial information system locates and tracks inventory using extremely low-power radio frequency tags and a communications network. Antennas positioned inside and outside the factory receive tag transmissions and deliver tracking information to a computer. The system then identifies the location of the tag within 10 feet of its exact position. Utilizing the same local infrastructure of antennas, Ford and WhereNet also co-developed a wireless call system known as WhereCall to bring parts to the line as needed. Ford implemented a third application of WhereNet's real-time locating technology - the Vehicle Inventory Management System (VIMS). The use of VIMS began as a pilot project in June 2000, at Ford's Michigan Truck Plant, which assembles thousands of vehicles daily.

This tracking system has reduced Ford's labor costs and produced other savings. The asset-tracking project was part of a broader program to improve the automaker's ability to follow a vehicle through the supply chain from the time a customer initiates an order until delivery. The program's ultimate goals include providing information to customers about the status of ordered vehicles and reducing the company's order-to delivery time to 15 days from about 60 days.

L. Walmart

Walmart has chosen radio-frequency identification (RFID) for tracking its inventory in warehouses and stores and replenishing them quickly. Walmart will use the Electronic Product Code (EPC) compliant RFID technology for identifying, tracking and tracing deliveries and inventory. The initiative targets to automate the supply chain cycles with all the manufacturers and suppliers starting Jan 2005.

M. Gillette

Gillette's system tracks its trucks through GPS locators and contents through RFID tags. It also alerts its suppliers about the real-time movement of its goods, giving them visibility and forecasting ability.

N. Marks & Spencer PLC

Company has moved forward with its test of tagging individual products with RFID tags to automate inventory and stocking. Company has all private-branded merchandise, as opposed to having to set up a system for multiple suppliers, making the implementation of this system easy. M&S has already achieved a 10% productivity increase in the fresh supply chain without increasing costs after it equipped about 60% of its suppliers with RFID.

At the time of this printing, there are other examples learned such as: Real-Time Information Management at Eastman Chemical; Automatic toll and payment collection system of EZPass employing RFID system.   These particular applications will be researched and noted in the next interim report.

5 Appendices

5.1 *OA Tables and Information flow diagrams*

Attributes/Media are captured in the tables only where wireless technology is needed for communication.

ORDER FULFILLMENT

5.1.1 Stocked Item

The Supported unit identifies a need for a product that must be fulfilled by the logistics chain (Garrison or Deployed). Product is stocked at the ISA. Product is on hand.

Step	Speaker	Listener	Performative	Content Description	Attributes/ Media	Descriptions
1.1	Supported Unit	Supervisor	Ask	Inform the requirement and ask for validation	Unit Identification, NSNs Quantity, Location, Expected time for replenishment. - **Text, Digital, Voice**	The request could be sent as an e-form. The location information is identified by the GPS enabled device and sent along with the form. The voice acts as a backup for human – human.
1.2	Supervisor	RM	Inform	After accepting the requirement	Secure signature - **Encryption**	Usually password encrypted
2.0	RM	OM	Inform	Submit and inform about the requirement on behalf of the using unit.	Request Identification + 1.1 - **Text, Digital**	In addition to the request form a request ID is automatically generated by the system which would be some digital information
3.1	OM	ICM	Ask /Accept	Ask the availability of the product and ICM agent either accepts or rejects.		
3.2	ICM	OM	Accept			

4.1	OM	DCM	Ask / Accept	Ask the availability of the Transportation for the distribution of the product and DCM accepts or rejects it.		
4.2	DCM	OM	Accept			
5.1	OM	ICM	Ask / Accept	Assess the capability of delivering the products if currently insufficient.		
5.2	ICM	OM	Accept			
6.1	OM	DCM	Ask / Accept	Assess the capability of making the distribution process available.		
6.2	DCM	OM	Accept			
7.0	OM	Supported Unit	Inform	Confirm with the supported unit by reiterating the requirement.	Request ID confirmation - **Text (short message) Voice**	Confirmation of the request can be achieved by sending the request ID back and forth with the customer.
8.1	OM	FM	Ask / Accept	Ask availability of finances FM either accepts or rejects.	List of materials, unit cost quantity, Total cost, customer ID Availability. - **Text, encryption, digital**.	The total cost for procurement is presented as an e-form. It is encrypted and sent for confirmation of availability of funds.
8.2	FM	OM	Accept			
9.0	OM	ICM	Inform	Request for the products and ask the ICM to reserve the products.		
10.0	OM	DCM	Inform	Informs in advance the need for distribution capacity for the reserved products.		
11.0	ICM	IPM	Reserve	Inform the IPM agent for reserving the products.	NSNs, Quantity, Order ID - **Text, Voice**	The specific list of consignments is sent so as to enable the IPM to reserve these products.
12.0	ICM	DCM	Inform	Signal the shipping requirements		
13.1	ICM/ DCM	DCM/ICM	Inform / Accept	Co-ordination for pick up		
13.2	ICM	OM	Inform	Signal the delivery requirements	ETD (expected time to delivery) Constraints - **Text, Voice**	The requirements for delivery such as expected time POC is sent to the OM.
14.1	IPM	IE	Request/Commit	Place a work order to the inventory execution element to make the product	NSNs, quantity, packing rqmts, Time to pick-up, Priority	The work order that contains the consignments

				ready for pick-up	- **Text, Voice, Digital**	to be made ready for delivery can be sent again as an e-form. The priority is a machine generated digital code.
14.2	IE	IPM	Accept			
15.0	DCM	DPM	Reserve	The specific products and number of products are asked to be reserved.	Transporting unit ID, Time to pick-up, Location - **Text, Voice, Digital**	The identified products are listed out and sent.
16.1	DPM	DE	Request/Commit	Place a work order for the pick-up and delivery of the products to the DE.	Consignment Labels, Location, Destination location, Product List. - **Text, Voice**	The location from where to pick-up the consignment labels and product lists are sent using both the e-forms and image files.
16.2	DE	DPM	Accept			
17.0	IE	IPM	Inform	Inform the Pick up list packaging labels & configuration	The package Labels, confirmation - **Text, Voice, Image**	The packages once reserved are identified by their labels and the information is sent using image files.
18.1	DE	DPM	Inform	Signal the delivery of the item	Signal - **Text, Digital, Voice**	The consignments that are delivered can be identified by their labels and signaled back upon delivery.
18.2	DPM	DCM	Inform	Route the signal from DE to DCM		
18.3	DCM	OM	Inform	Signal item delivery to OM agent		
19.0	OM	Supported Unit	Ask / Accept	Checks with the Supported unit if the products were received or not.	Signal, signature, Receipt - **Text, Digital**	The delivered consignment labels are sent and verified by the customer.
20.0	OM	FM	Inform	Receipt for delivery.	Invoice - **Text, encryption, digital**	An invoice for financial claims is sent using e-forms and encryption techniques.
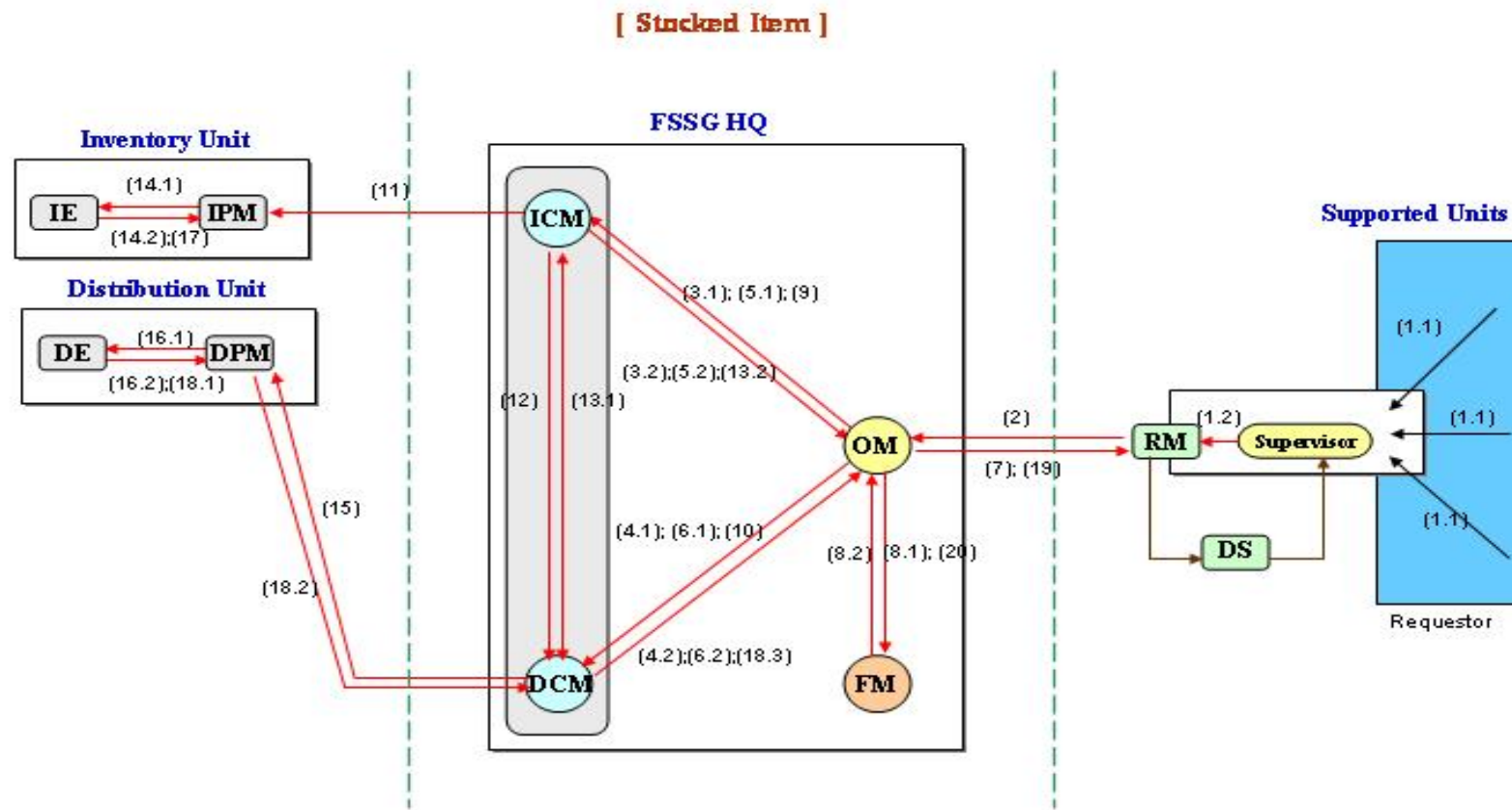
Figure 5.1.1 Stocked Item

5.1.2 Non-Stocked Item

The supported unit identifies a need for a product that must be fulfilled by the logistics chain (Garrison or Deployed).

Product is not on hand at the ISA.

	Speaker	Listener	Performative	Content Description	Attributes/ Media	Descriptions
Same with Step 1.1 to 10.0 in Stocked Item Case						
11.1	ICM	PCM	Inform	Signal PCM about the requirements		
11.2	PCM	PPM	Ask / Accept	PCM asks PPM to reserve the products and make available for distribution.	NSNs, Quantity, Order ID - **Text, Voice**	The specific list of consignments is sent so as to enable the PPM to reserve these products.
11.3	PPM	PE	Request - Commit	PPM requests to source and reserve the items.	NSNs, quantity, packing rqmts, Time to pick-up, Priority - **Text, Voice, Digital**	The work order that contains the consignments to be made ready for delivery can be sent as an e-form. The priority is a machine generated digital code.
11.4.1	PE	PPM	Inform	PE signals the capability to PPM	Signal - **Digital, Text**	The availability of the products are confirmed by a digital code or using a text form.
11.4.2	PPM	PCM	Inform	PPM signals PCM about the availability of the products once signal is received from PE.	Signal - **Digital, Text**	The signal received from PE if routed to PCM.
11.4.3	PCM	ICM	Inform	PCM signals to ICM that the items will be made available. The items are placed as back-orders.		
11.4.4	ICM	OM	Commit	Informs OM that the items are available to promise	Order ID, Confirmation - **Text, Voice**	The order id is reiterated to the OM and the products are confirmed as available to promise.
12.0	ICM	DCM	Inform	Signals the shipping requirements		
13.1	DCM/ICM	ICM/DCM	Ask / Accept	Co-ordination for Pick-up for delivery.		

13.2	ICM	OM	Inform	ICM signals OM, so as to enable OM to manage the fulfillment issues.	Order ID, Packaging info, time to pick up. - **Text, Voice**	
13.3	ICM	IPM	Request/Commit			
13.3	IPM	IE	Request/Commit	IPM orders IE for the receiving the delivery from the external source.	Order ID, Consignment Labels, Time to delivery -**Text, Voice, Image**	The Labels of the consignment are sent using image files while the list and time information can be sent using Text forms.
14.1	IE	IPM	Inform	Notifies IPM upon receiving the orders from the external source	Receipt - **Text, Voice**	The receipt generated upon receiving the order will be in text form, a verbal confirmation may be used to supplement the communication.
14.2	IPM	ICM	Inform	Signals ICM about the receipt of the orders	Receipt - **Text, Voice**	The receipt is routed to ICM node.
14.3	ICM	OM	Inform	Signals OM about the orders received.	Signal - **Text, Voice**	Sends a confirmation of receipt.
14.4	OM	FM	Inform	Notifies FM that the products were received from the external source and a receipt is sent.	Invoice - **Text, Encryption**	The financial invoice for transfer of funds is sent as text but needs to be encrypted.
Same with Step 15.0 to 20.0 in Stocked Item Case						

Figure 5.1.2 Non-Stocked Item

5.1.3 Multiple Source Item

The supported unit identifies a need for multiple products that must be fulfilled by the logistics chain (Garrison or Deployed). Products are cataloged items and acquired from multiple sources and delivered as a completed layette. Internal items are not sourced from multiple organic warehouses, but some items are sourced from the same warehouse where the layette is being built.

Step	Speaker	Listener	Performative	Content Description	Attributes/ Media	Descriptions
Same with Step 1.1 to 3.0 in Stocked Item Case						
3.3	ICM	PCM	Ask	Check ability/availability to acquire products		
3.4	PCM	ICM	Accept			
Same with Step 4.0 to 10.0 in Stocked Item Case						
9.2	ICM	PCM	Inform	Source external items		
9.3	ICM	OM	Inform	Informs NS2.1 to OM		
Same with Step 11.0 to 14.0 in Stocked Item Case						
14.2	IE	IPM	Inform	Informs 21.1		
14.3	IPM	ICM	Inform	Informs 21.1		
14.4	ICM	OM	Inform	Informs 21.1		
14.5	OM	FM	Inform	Signals of receipt verification of external items.		
Same with Step 15.0 to 20.0 in Stocked Item Case						
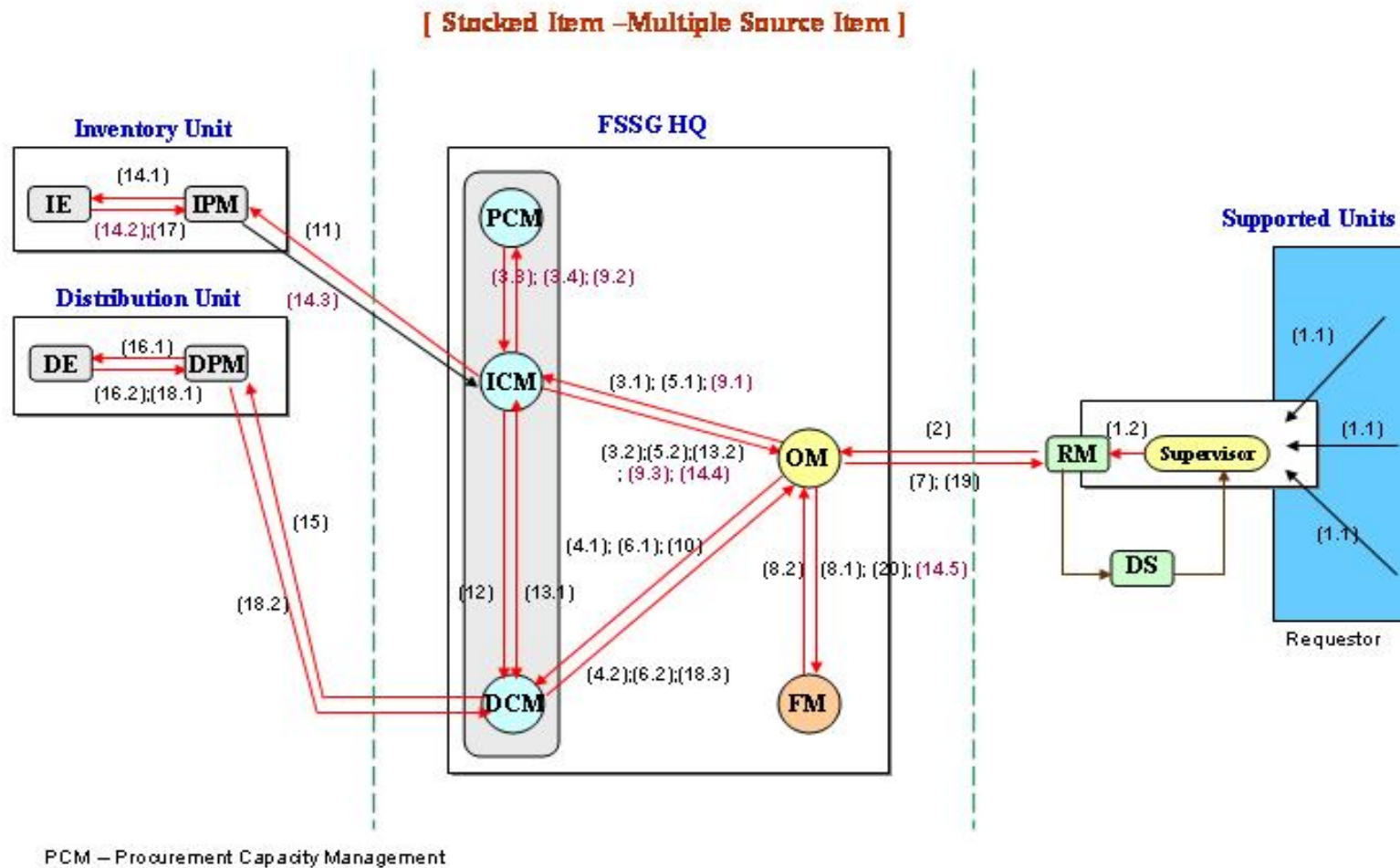
Figure 5.1.3 Stocked Item-Multiple Source Item

Return Processes

5.1.4 Return of Excess Item to Stock

Supported unit identifies a need for a serviceable excess product return (Garrison or Deployed). Product is a cataloged item.

Step	Speaker	Listener	Performative	Content Description	Attributes/ Media	Descriptions
1.1	Supported Unit	Supervisor	Ask	Inform the requirement to put away/return the items from local inventory to the stock. Ask supervisor for validation.	Unit Identification, NSNs Quantity, Location - **Text, Digital, Voice**	The request could be sent as an e-form. The location information is identified by the GPS enabled device and sent along with the form. The voice acts as a backup for human – human.
1.2	Supervisor	RM	Inform	After accepting the need to return the items	Secure signature - **Encryption**	Usually password encrypted
2.0	RM	OM	Inform	Submit and inform about the requirements on behalf of the using unit.	Request Identification + 1.1 - **Text, Digital**	In addition to the request form a request ID is automatically generated by the system which would be some digital information
3.0	OM	ICM	Ask / Accept	Ask the availability of resources (storage capacity and man power) and ICM either accepts or rejects.		
4.0	OM	DCM	Ask / Accept	Ask the availability of the Transportation for the pick up of products from the using unit and DCM accepts or rejects it.		
5.0	OM	ICM	Ask / Accept	Assess the capability of ICM to accepting the products.		
6.0	OM	DCM	Ask / Accept	Assess the capability of DCM for making the distribution resources available.		
7.0	OM	Supported Unit	Inform	Confirm with the Supported unit by reiterating the requirement and the terms and conditions for pick up and return.	Request ID confirmation - **Text (short message) Voice**	Confirmation of the request can be achieved by sending the request ID back and forth with the customer.
8.0	OM	FM	Ask / Accept	Optional – In case funds are to be credited for the return then OM asks FM about	- **Text, encryption, digital**.	The total cost for procurement is presented as

				availability of the funds.		an e-form. It is encrypted and sent for confirmation of availability of funds.
9.0	OM	ICM	Inform	Inform ICM to reserve and schedule the resources.		
10.0	OM	DCM	Inform	Informs in advance the need for distribution capacity for the products to be returned.		
11.0	ICM	IPM	Reserve	Inform IPM to reserve and schedule the necessary resources for products return. (storage capacity, man power etc)	Order ID, NSNs - **Text, Voice**	The specific list of consignments is sent so as to enable the IPM to reserve the resources.
12.0	ICM	DCM	Inform	Signal the shipping requirements		
13.1	ICM/ DCM	DCM/ICM	Inform / Accept	Co-ordination for pick up		
13.2	ICM	OM	Inform	Signal the delivery requirements		The requirements for delivery such as expected time POC is sent to the OM.
14.0	IPM	IE	Request/Commit	Place a work order to the inventory execution element to make the resources ready for accepting returned products.	NSNs, quantity, packing rqmts, Time to receive, Priority - **Text, Voice, Digital**	The work order that contains the resources that need to be reserved can be sent again as an e-form. The priority is a machine generated digital code.
15.0	DCM	DPM	Reserve	The specific resources are reserved.	Transporting unit ID, Time to pick-up, Location - **Text, Voice, Digital**	The identified products are listed out and sent.
16.0	DPM	DE	Request/Commit	Place a work order for the pick-up from using unit and delivery to the ICM of the products to be returned.	Consignment ID, Location, Destination location, Product List. - **Text, Voice**	The location from where to pick-up the products is sent using both the e-forms and image files.
17.0	OM	Supported unit	Inform	Inform the need to stage products (keep ready for pick-up)	Confirmation - **Text, Voice, Image**	The packages once reserved are identified by their labels and the information is sent using image files.
18.1	DE	DPM	Inform	Signal the delivery of the item	Signal - **Text, Digital, Voice**	The consignments that are delivered can be identified by their labels and signaled

						back upon delivery.
18.2	DPM	DCM	Inform	Route the signal from DE to DCM	Signal - **Text, Digital, Voice**	
18.3	DCM	OM	Inform	Signal item delivery to OM agent		
19.0	IE	IPM	Inform	Verify the received items, record and report the details and discrepancies to IPM	Signal, signature, Receipt - **Text, Digital**	The delivered consignment labels are sent and verified by the customer.
20.0	OM	Supported unit	Ask	Receipt for fulfillment of the request	Invoice - **Text, encryption, digital**	A receipt is sent using e-forms and encryption techniques.
21.0	OM	FM	Inform	Optional – Signal about the receipt and expenses if necessary.	**- Text, encryption, digital**	Invoice
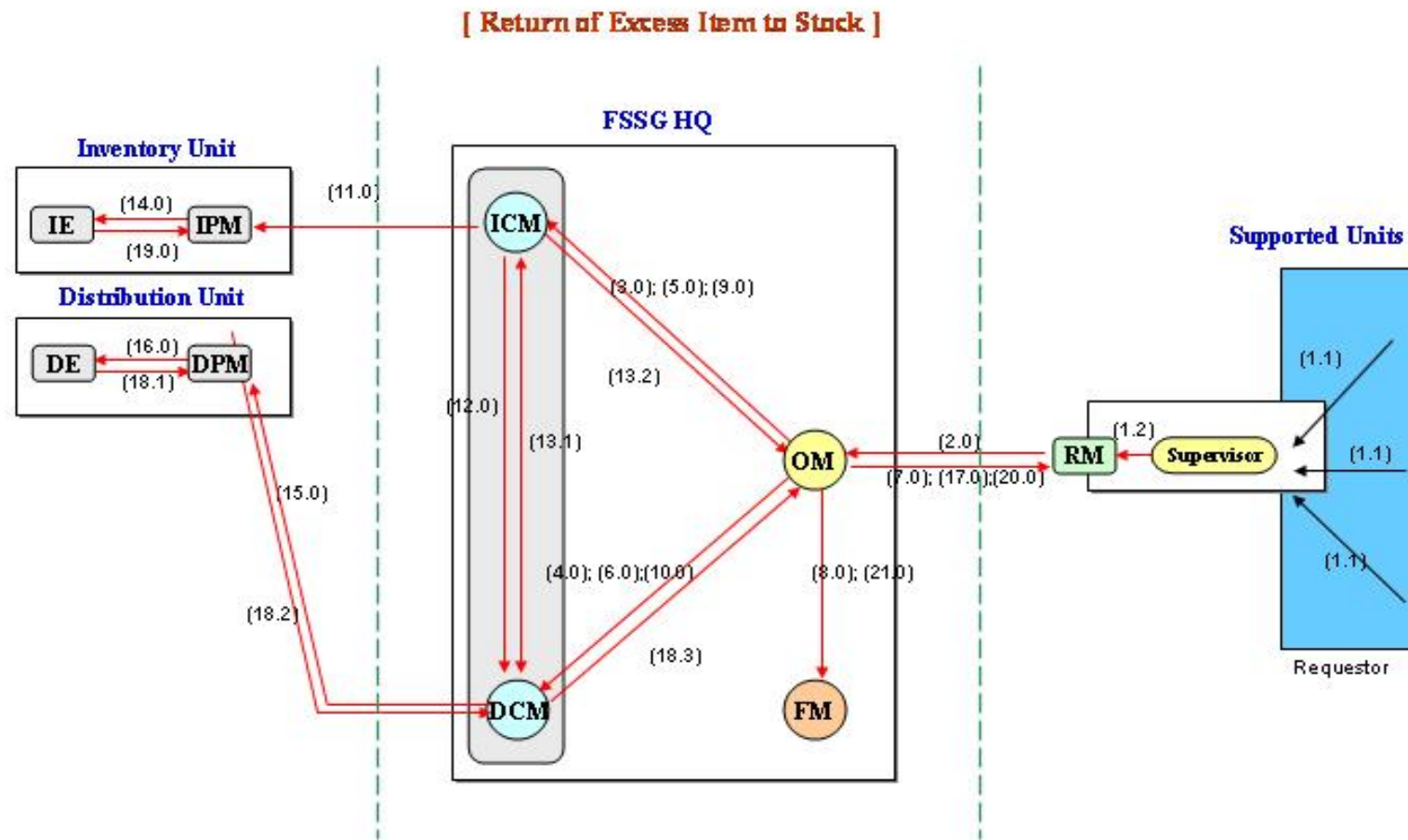
Figure 5.1.4 Return of Excess Item to Stock

5.1.5 Return of MRO to Stock

Supported unit identifies a need for a product return due to MRO (Garrison or Deployed). Product is a cataloged item.

Step	Speaker	Listener	Performative	Content Description	Attributes/ Media	Descriptions
1.1	Supported Unit	Supervisor	Ask	Inform the requirement to put away/return the items from local inventory to the stock. Ask supervisor for validation.	Unit Identification, NSNs Quantity, Location, Expected time for replenishment. - **Text, Digital, Voice**	The request could be sent as an e-form. The location information is identified by the GPS enabled device and sent along with the form. The voice acts as a backup for human – human.
1.2	Supervisor	RM	Inform	After accepting the need to return the items	Secure signature - **Encryption**	Usually password encrypted
2.0	RM	OM	Inform	Submit and inform about the requirements on behalf of the using unit.	Request Identification + 1.1 - **Text, Digital**	In addition to the request form a request ID is automatically generated by the system which would be some digital information
3.1	OM	MCM	Ask / Accept	Ask the availability of resources (Tools and man power) and MCM either accepts or rejects.		
3.2	MCM	OM	Accept			
4.1	OM	ICM	Ask / Accept	Ask the availability of resources to receive the product.		
4.2	ICM	OM	Accept			
5.1	OM	DCM	Ask / Accept	Ask the availability of the Transportation for the pick up of products from the using unit and DCM accepts or rejects it.		
5.2	DCM	OM	Accept			
6.1	OM	MCM	Ask / Accept	Assess the capability of MCM to make the repair within the relevant conditions of time.		
6.2	MCM	OM	Accept			

7.1	OM	ICM	Ask / Accept	Assess the availability of resources at ICM to receive the product within specified conditions.		
7.2	ICM	OM	Accept			
8.1	OM	DCM	Ask / Accept	Assess the availability of the Transportation for the pick up of products from the using unit and DCM accepts or rejects it		
8.2	DCM	OM	Accept			
9.0	OM	Supported Unit	Inform	Confirm with the Supported unit by reiterating the requirement and the terms and conditions for pick up and repair.	Request ID confirmation - **Text (short message) Voice**	Confirmation of the request can be achieved by sending the request ID back and forth with the customer.
10.1	OM	FM	Ask / Accept	Optional – In case funds are to be credited for the return then OM asks FM about availability of the funds.	- **Text, encryption, digital**.	The total cost repair is presented as an e-form. It is encrypted and sent for confirmation of availability of funds.
10.2	FM	OM	Accept			
11.0	OM	MCM	Inform	Inform MCM to reserve and schedule the resources.		
12.0	OM	DCM	Inform	Informs in advance the need for distribution capacity for the products to be returned.		
13.0	OM	ICM	Inform	Informs in advance the need for resources to receive the product.		
14.0	MCM	MPM	Inform	Inform MPM to reserve and schedule the resources for fulfilling the repair.	Order ID, NSNs - **Text, Voice**	The specific list of resources is sent so as to enable the IPM to reserve the resources.
15.0	MCM	DCM	Inform	Inform the relevant shipping requirements.		
16.1	MCM/ DCM	DCM/MC M	Inform / Accept	Co-ordination for pick up		
16.2	DCM/MC M	MCM/ DCM	Accept			
16.3	MCM	OM	Inform	Signal the delivery requirements		
17.1	MPM	ME	Inform	Assigns the resources from the execution element for this particular task.	Work order ID, Item ID - **Text, Voice**	Generated work order is sent to the ME so as perform the required tasks.

17.2	ME	MPM	Accept			
18.0	DCM	DPM	Reserve	The specific resources are reserved.	Transporting unit ID, Time to pick-up, Location - **Text, Voice, Digital**	The identified products are listed out and sent.
19.1	DPM	DE	Inform	Place a work order for the pick-up from using unit and delivery to the MCM of the products to be repaired.	Item ID, Location, Destination location - **Text, Voice**	The location from where to pick-up the item and product lists are sent using the e-forms.
19.2	DE	DPM	Accept			
20.0	OM	Supported Unit	Inform	Inform the Supported unit to stage the product for pick-up by DE.	Signal -**Text (Short message), Voice**	Message asking the using unit to stage item.
DE now picks up the staged product from the supported unit and delivers it to the assigned ME unit.						
21.1	DE	DPM	Inform	Inform the delivery of the product.	Signal - **Text, Digital, Voice**	The item that is delivered can be identified by their ID and signaled back upon delivery.
21.2	DPM	DCM	Inform	Route the signal from DE to DCM	Signal - **Text, Digital, Voice**	The item that is delivered can be identified by their ID
21.3	DCM	OM	Inform	Route the signal received from DPM to OM and inform the delivery of the product.		
22.1	MCM/ ICM	ICM/MCM	Inform / Accept	Co-ordination for taking custody of the assets.		
22.2	ICM/MCM	MCM/ ICM	Accept			
ME now conducts diagnosis and inspection						
23.0	ME	MPM	Inform	It conveys to MPM the additional resource requirements if necessary.		Optional
MPM identifies and requests the additional resources and parts to effect repair if necessary.						
24.0	MPM	MCM	Inform	Send the signal about the additional resource requirements.		Optional
25.1	MCM	ICM	Ask/Accept	Request for the additional resources that are required.		Optional
25.2	ICM	MCM	Accept			
ME then performs the repair and checks for quality.						

26.1	MCM	ICM	Inform	Requirements for returning the item.		
26.2	ICM	IPM	Inform	Ask IPM to reserve and schedule the resources for accepting the repaired item.	NSNs, Quantity, Order ID, Time frame. - **Text, Voice**	The list and quantity of items and time frame can be sent using text forms.
27.0	ICM	DCM	Inform	Notify DCM about the shipping requirements.		
28.1	DCM/ ICM	ICM/DCM	Inform / Accept	Co-ordination for pick up and delivery of the repaired item.		
28.2	ICM/DCM	DCM/ ICM	Accept			
28.3	ICM	MCM	Inform	Inform that the item is ready for return.		
28.4	ICM	OM	Inform	Inform that the item is ready for return.		
29.1	IPM	IE	Inform	Generate and direct IE to schedule resources for receiving the returned item..	NSNs, quantity, packing rqmts, Time to receive, Priority - **Text, Voice, Digital**	The work order that contains the resources to be made ready for receiving can be sent again as an e-form. The priority is a machine generated digital code.
29.2	IE	IPM	Accept			
30.0	DCM	DPM	Inform	Reserve and schedule the resources for pickup and delivery of the repaired item.	Transporting unit ID, Time to pick-up, Location - **Text, Voice, Digital**	The identified products are listed out and sent.
31.0	DPM	DE	Inform	Generate and direct work order to pick up and deliver the repaired item to IE.	Item ID, Location, Destination location - **Text, Voice**	The location from where to pick-up the item and product lists are sent using the e-forms.
The Item is picked up and returned to the designated IE/IPM by the distribution execution element.						
32.1	DE	DPM	Inform	Signal about the delivery of the item	Signal - **Text, Digital, Voice**	The item that is delivered can be identified by their ID and signaled back upon delivery.
32.2	DPM	DCM	Inform	Route the signal received from DE to DCM	Signal - **Text, Digital, Voice**	The item that is delivered can be identified by their ID and signaled back to DCM.

32.3	DCM	OM	Inform	Route the signal received from DPM to OM and confirm delivery.		
33.1	IE	IPM	Inform	Verifies records and reports discrepancies about the item received	NSN, Description of item quality - **Text, Voice**, **Digital**	The condition of the received item is sent as text.
33.2	IPM	ICM	Inform	Routes the information about the received product to ICM	NSN, Description of item quality - **Text, Voice**, **Digital**	The condition of the received item is sent as text.
33.3	ICM	OM	Inform	The information about received item is notified to OM. Receipt		
34.0	OM	FM	Inform	Liquidate funds if required.	Invoice - **Text, Encryption, Digital**	The invoice is sent as text with encryption.

Figure 5.1.5 Return of MRO to Stock

5.1.6 Return of Defective Item to Source

Supported unit identifies a need for a product return due to defects (Garrison or Deployed). Product does not require to be replaced.

Step	Speaker	Listener	Performative	Content Description	Attributes/ Media	Descriptions
1.1	Supported Unit	Supervisor	Ask	Inform the requirement to put away/return the items from local inventory to the stock. Ask supervisor for validation.	Unit Identification, NSN Quantity, Location, Expected time for disposition - **Text, Digital, Voice**	The request could be sent as an e-form. The location information is identified by the GPS enabled device and sent along with the form. The voice acts as a backup for human – human.
1.2	Supervisor	RM	Inform	After accepting the need to return the items	Secure signature - **Encryption**	Usually password encrypted
2.0	RM	OM	Inform	Submit and inform about the requirements on behalf of the using unit.	Request Identification + 1.1 - **Text, Digital**	In addition to the request form a request ID is automatically generated by the system which would be some digital information
3.0	OM	ICM	Ask / Accept	Ask the availability of resources (storage capacity and man power) and ICM either accepts or rejects.		
4.0	OM	DCM	Ask / Accept	Ask the availability of the Transportation for the pick up of products from the using unit and DCM accepts or rejects it.		
5.0	OM	ICM	Ask / Accept	Assess the capability of ICM to accepting the products.		
6.0	OM	DCM	Ask / Accept	Assess the capability of DCM for making the distribution resources available.		
7.0	OM	Supported Unit	Inform	Confirm with the Supported unit by reiterating the requirement and the terms and conditions for pick up and return.	Request ID confirmation - **Text (short message) Voice**	Confirmation of the request can be achieved by sending the request ID back and forth with the customer.
8.0	OM	FM	Ask / Accept	Optional – In case funds are to be credited for the return then OM asks FM about availability of the funds.	List of materials, customer ID Availability.	The availability of funds if it is to be credited has to be sent. It is encrypted before

					- **Text, encryption, digital**.	sending.
9.0	OM	ICM	Inform	Inform ICM to reserve and schedule the resources.		
10.0	OM	DCM	Inform	Informs in advance the need for distribution capacity for the products to be returned.		
11.0	ICM	IPM	Reserve	Inform IPM to reserve and schedule the necessary resources for products return. (storage capacity, man power etc)	NSN, Quantity, Order ID - **Text, Voice**	The specific list of items is sent so as to enable the IPM to reserve the resources.
12.0	ICM	DCM	Inform	Signal the shipping requirements		
13.1	ICM/ DCM	DCM/ICM	Inform / Accept	Co-ordination for pick up		
13.2	ICM	OM	Inform	Signal the delivery requirements		The requirements for delivery such as expected time POC is sent to the OM.
14.0	IPM	IE	Request/Commit	Place a work order to the inventory execution element to make the resources ready for accepting returned products.	NSNs, quantity, packing rqmts, Time to receive, Priority - **Text, Voice, Digital**	The work order that contains the resources to be made ready for receiving can be sent again as an e-form. The priority is a machine generated digital code.
15.0	DCM	DPM	Reserve	The specific resources are reserved.	Transporting unit ID, Time to pick-up, Location - **Text, Voice, Digital**	The identified products are listed out and sent.
16.0	DPM	DE	Request/Commit	Place a work order for the pick-up from using unit and delivery to the ICM of the products to be returned.	Item ID, Location, Destination location, Product List. - **Text, Voice**	The location from where to pick-up the item and product lists are sent using both the e-forms and image files.
17.0	OM	Supported unit	Inform	Inform the need to stage products (keep ready for pick-up)	- **Text, Voice**	
18.1	DE	DPM	Inform	Signal the delivery of the item	Signal - **Text, Digital, Voice**	The items that are delivered can be identified by their labels and signaled back upon delivery.
18.2	DPM	DCM	Inform	Route the signal from DE to DCM		

18.3	DCM	OM	Inform	Signal item delivery to OM agent		
19.1	IE	IPM	Inform	Verify the received items, record and report the details and discrepancies to IPM	Signal, signature, Receipt - **Text, Digital**	The delivered item list is sent.
19.2	IPM	ICM	Inform	Route the information to ICM		
19.3	ICM	OM	Inform	Notify the information to OM		
20.0	ICM	DCM	Inform	The shipping requirements have to be informed to DCM		
21.1	ICM/ DCM	DCM/ICM	Inform / Accept	Co-ordination for pick up		
21.2	ICM	OM	Inform	Signal the delivery requirements		
22.0	DCM	DPM	Inform	Direct the DPM to reserve and make schedule for the necessary transportation resources.	Transporting unit ID, Time to pick-up, Location - **Text, Voice, Digital**	The identified products are listed out and sent.
23.0	DPM	DE	Inform	Generate work order and route it to the relevant DE for fulfilling the work.	Item ID, Location, and Destination location, Product List. - **Text, Voice**	The location from where to pick-up the item and product lists are sent using both the e-forms and image files.
* DE now transfers the defective products to the relevant external source. Upon receiving the items a signal is generated to inform the DPM about completion of the work order.						
24.1	DE	DPM	Inform	Signal the delivery of the item	Signal - **Text, Digital, Voice**	The consignments that are delivered can be identified by their labels and signaled back upon delivery.
24.2	DPM	DCM	Inform	Route the signal from DE to DCM	Signal - **Text, Digital, Voice**	The consignments that are delivered can be identified by their labels and signaled back upon delivery.
24.3	DCM	OM	Inform	Signal item delivery to OM agent		
25.0	OM	External source	Inform	Send a confirmation for the receipt received and verified.	Signal, signature, Receipt - **Text, Digital**	The received item list is sent.
21.0	OM	FM	Inform	Optional – Signal about the receipt and expenses if necessary.	**- Text, encryption, digital**	Invoice
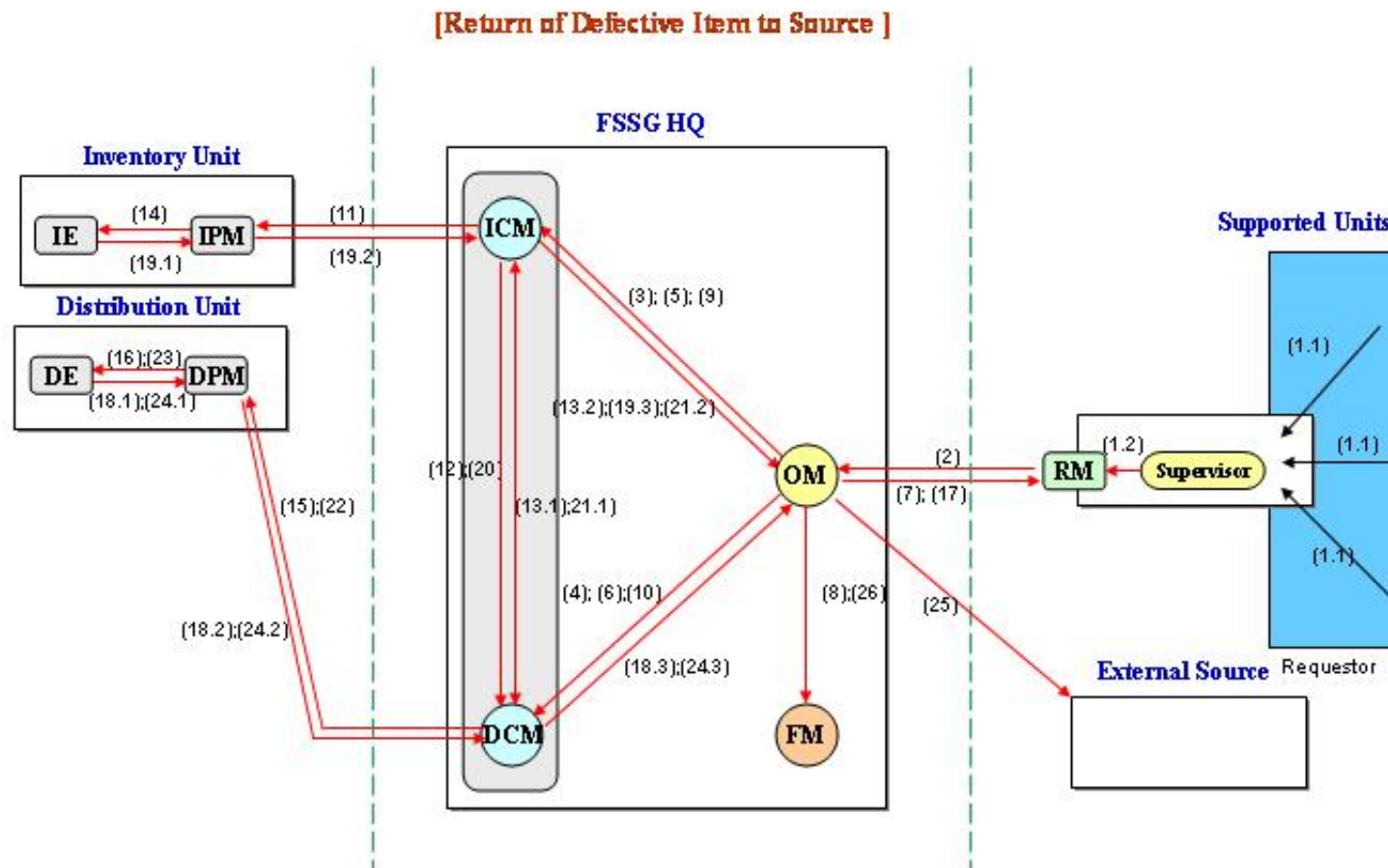
Figure 5.1.6 Return of Defective Item to Source

5.1.7 Return of Hazardous Material for Disposal

Supported unit identifies a need for return of a Hazardous Material to include waste (Garrison or Deployed) for disposal.

Step	Speaker	Listener	Performative	Content Description	Attributes/ Media	Descriptions
1.1	Supported Unit	Supervisor	Ask	Inform the requirement to put away/return the items. Ask supervisor for validation.	Unit Identification, NSNs Quantity, Location - **Text, Digital, Voice**	The request could be sent as an e-form. The location information is identified by the GPS enabled device and sent along with the form. The voice acts as a backup for human – human.
1.2	Supervisor	RM	Inform	After accepting the need to return the items	Secure signature - **Encryption**	Usually password encrypted
2.0	RM	OM	Inform	Submit and inform about the requirements on behalf of the Supported Unit.	Request Identification - **Text, Digital**	In addition to the request form a request ID is automatically generated by the system which would be some digital information
3.0	OM	ICM	Ask / Accept	Ask the availability of the special handling requirements.		
4.0	OM	DCM	Ask / Accept	Ask the availability of the Transportation for the pick up of products from the supported unit and DCM accepts or rejects it.		
5.0	OM	ICM	Ask / Accept	Assess the capability of ICM to accepting the products.		
6.0	OM	DCM	Ask / Accept	Assess the capability of DCM for making the distribution resources available.		
7.0	OM	Supported Unit	Inform	Confirm with the using unit by reiterating the requirement and the terms and conditions for pick up and return.	Request ID confirmation - **Text (short message) Voice**	Confirmation of the request can be achieved by sending the request ID back and forth with the customer.
8.0	OM	FM	Ask / Accept	Optional – In case funds are to be credited for the return then OM asks FM about availability of the funds.	- **Text, encryption, digital**.	The total cost for disposal is presented as an e-form. It is encrypted and sent for

						confirmation of availability of funds.
9.0	OM	ICM	Inform	Inform ICM to reserve and schedule the resources.		
10.0	OM	DCM	Inform	Informs in advance the need for distribution capacity for the products to be returned.		
11.0	ICM	IPM	Reserve	Inform IPM (disposal) to reserve and schedule the necessary resources for products disposal. (Man power, safety requirements etc)	Order ID, NSNs - **Text, Voice**	The specific list of consignments is sent so as to enable the IPM to reserve the resources.
12.0	ICM	DCM	Inform	Signal the shipping requirements		
13.1	ICM/ DCM	DCM/ICM	Inform / Accept	Co-ordination for pick up		
13.2	ICM	OM	Inform	Signal the delivery requirements		The requirements for delivery such as expected time POC is sent to the OM.
14.0	IPM	IE	Request/Commit	Place a work order to the inventory execution element to make the resources ready for disposing returned products.	NSNs, quantity, packing rqmts, Time to receive, Priority - **Text, Voice, Digital**	The work order that contains the resources that need to be reserved can be sent again as an e-form. The priority is a machine generated digital code.
15.0	DCM	DPM	Reserve	The specific resources are reserved.	Transporting unit ID, Time to pick-up, Location - **Text, Voice, Digital**	The identified products are listed out and sent.
16.0	DPM	DE	Request/Commit	Place a work order for the pick-up from using unit and delivery to the ICM of the products to be returned.	Consignment ID, Location, Destination location, Product List. - **Text, Voice**	The location from where to pick-up the material is sent using both the e-forms and image files.
17.0	OM	Supported Unit	Inform	Inform the need to stage products (keep ready for pick-up)	Confirmation - **Text, Voice, Image**	
18.1	DE	DPM	Inform	Signal the delivery of the item	Signal - **Text, Digital, Voice**	
18.2	DPM	DCM	Inform	Route the signal from DE to DCM	Signal - **Text, Digital, Voice**	

18.3	DCM	OM	Inform	Signal item delivery to OM agent		
19.0	IE	IPM	Inform	Verify the received items, record and report the details of disposal according to specifications.	Signal, signature, Receipt - **Text, Digital**	The delivered material description are sent and verified by the customer.
20.1	IE	IPM	Inform	Signal completion of disposal for hazardous material according to specification.		
20.2	IPM	ICM	Inform	Signal completion of disposal for hazardous material according to specification.		
20.3	ICM	OM	Inform	Signal completion of disposal for hazardous material according to specification.		
21.0	OM	Supported unit	Ask	Receipt for fulfillment of the request	Invoice - **Text, encryption, digital**	A receipt is sent using e-forms and encryption techniques.
22.0	OM	FM	Inform	Optional – Signal about the receipt and expenses if necessary.	- **Text, encryption, digital**	Invoice
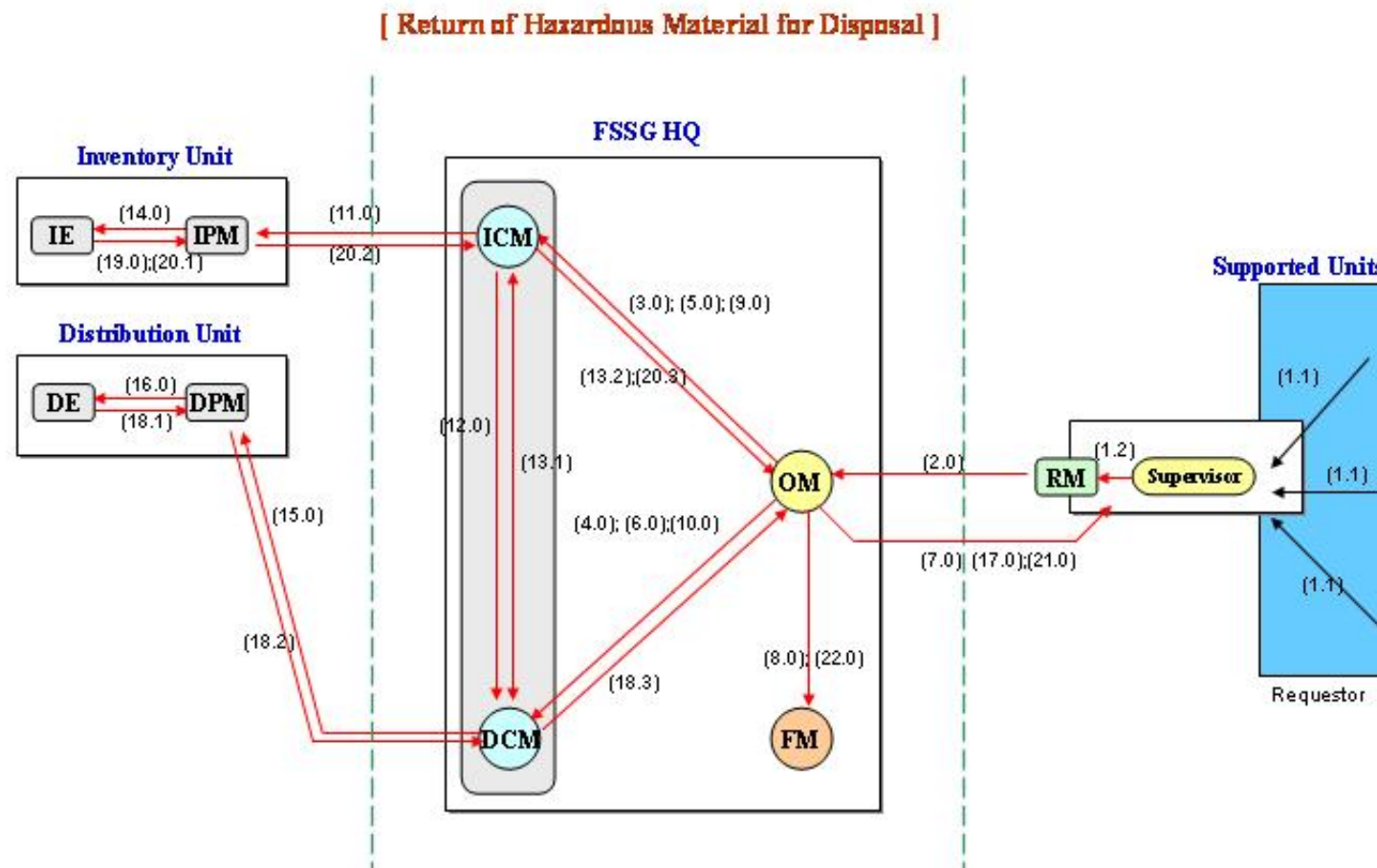
Figure 5.1.7 Return of Hazardous Material for Disposal

MAINTENANCE

5.1.8 Maintenance at IMA

Supported unit identifies a need for a maintenance service that must be fulfilled by the logistics chain (Garrison or deployed). Intermediate maintenance activity (IMA) has capability to perform this service. Service performed at maintenance site. This scenario applies to both parts on hand and for parts out of stock, and applies both scheduled and unscheduled maintenance.

Step	Speaker	Listener	Performative	Content Description	Attributes/ Media	Comments
1.1	Supported Unit	Supervisor	Ask	The supported unit identifies requirement and a request is sent to the supervisor for validation.	Unit Identification, Location; - **Text, Digital, Voice**	The request could be sent as an e-form. The location information is identified by the GPS enabled device and sent along with the form. The voice acts as a backup for human – human.
1.2	Supervisor	RM	Inform	The supervisor validates and prioritizes the requirement and sends it to RM	Secure signature - **Encryption**	Usually password encrypted
2.0	RM	OM	Inform	Submit and inform about the requirements on behalf of the supported unit if unable to source internally.	Request Identification + 1.1 - **Text, Digital**	In addition to the request form a request ID is automatically generated by the system which would be some digital information
3.1	OM	MCM	Ask	Ask the availability of resources (tools, man power, parts) and MCM either accepts or rejects.		
3.2	MCM	OM	Accept	MCM accepts or rejects the request.		
4.1	OM	DCM	Ask	Ask the availability of the Transportation for the pick up of products from the using unit.		
4.2	DCM	OM	Accept	DCM accepts or rejects the request		
5.1	OM	MCM	Ask	Assess the capability of ICM to accepting the products.		
5.2	MCM	OM	Accept			

6.1	OM	DCM	Ask / Accept	Assess the capability of DCM for making the distribution resources available.		
6.2	DCM	OM	Accept			
7.0	OM	Supported Unit	Inform	Confirm with the using unit by reiterating the requirement and the terms and conditions for the maintenance.	Request ID confirmation - **Text (short message) Voice**	Confirmation of the request can be achieved by sending the request ID back and forth with the customer.
8.1	OM	FM	Ask / Accept	**Optional** – In case funds are to be credited for the maintenance then OM asks FM about availability of the funds.	- **Text, encryption, digital**.	The total cost repair is presented as an e-form. It is encrypted and sent for confirmation of availability of funds.
8.2	FM	OM	Accept			
9.0	OM	MCM	Inform	Inform MCM to reserve and schedule the maintenance.		
10.0	OM	DCM	Inform	Informs in advance the need for distribution capacity for the maintenance.		
11.0	MCM	MPM	Inform	Inform MPM to reserve and schedule the relevant resources to fulfill the work order.	Order ID, Requirements - **Text, Voice**	The specific list of resources is sent so as to enable the MPM to reserve the resources.
12.0	MCM	DCM	Inform	Inform the relevant shipping requirements.		
13.0	MCM/ DCM	DCM/MC M	Inform / Accept	Co-ordination for pick up		
14.0	MCM	OM	Inform	Signal the delivery requirements	Order ID, Shipping requirements - **Text, Voice**	
15.1	MPM	ME	Inform	Assigns the resources from the execution element for this particular task.	Work order ID, Item ID - **Text, Voice**	Generated work order is sent to the ME so as perform the required tasks.
15.2	ME	MPM	Inform			
16.0	DCM	DPM	Reserve	The specific resources are reserved.	Transporting unit ID, Time to pick-up, Location - **Text, Voice, Digital**	The identified products are listed out and sent.
17.1	DPM	DE	Inform	Place a work order for the pick-up from using unit and delivery to the MCM of the products to be repaired.	Item ID, Location, Destination location - **Text, Voice**	The location from where to pick-up the item and product lists are sent using the e-forms.

17.2	DE	DPM	Inform			
18.0	OM	Supported Unit	Inform	Signals to stage product so that it can be taken by DE to the ME site.	Signal - **Text (short message)**	
ME remove the items requiring repair to the maintenance site.						
19.0	DE	ME	Inform	Signal delivery of the item	Signal - **Text (short message)**	
20.1	DE	DPM	Inform	Signal delivery of the item	Signal - **Text (short message)**	
20.2	DPM	DCM	Inform	Passes on the signal from DE to DCM	Signal - **Text (short message)**	
20.3	DCM	OM	Inform	The signal taken from DPM is informed to OM.		
ME receive item.						
21.1	ME	MPM	Inform	Informs MPM about the receipt of the item		
21.2	MPM	MCM	Inform	MPM forwards the signals about receipt of item to MCM.		
21.3	MCM	OM	Inform	MCM informs OM about the receipt of the item.		
ME now conduct disassembly if required, diagnosis and inspection, and capture the cause of failure. MPM identifies and requests the additional resources and parts to effect repair if necessary.						
22.0	MPM	MCM	Ask	Send the signal about the additional resource and parts requirements to affect repair.		
23.0	MCM	OM	Inform	Based on the need for additional resources MCM now reiterates the need capability of fulfilling the request on time.		
24.0	OM	Supported Unit	Inform	If required OM now notifies the supported unit about the new ATP/CTP conditions and its capability to fulfill the request.		
25.0	OM	FM	Inform	Fund requirements are informed to FM if needed, Optional.		
26.0	MCM	xCM	Inform	Signals for additional resources and parts and reserves these resources. This is done only if the additional resources are not available internally.		
ME performs repair and conducts quality control.						

27.1	ME	MPM	Inform	Notify repair completion.		
27.2	MPM	MCM	Inform	Signal repair completion.		
27.3	MCM	OM	Inform	Forward the signal received from MPM about the completion of the task to OM.		
ME stages repaired item for return to customer, and MPM releases repaired item.						
28.0	MCM	DCM	Inform	Notify shipping requirements.		
29.1	DCM/ MCM	MCM/ DCM	Inform/Accept	Co-ordination for pick-up to meet delivery requirements.		
29.2	MCM	OM	Inform	Notify about the release of item from MCM and requirements of pick up.		
30.0	DCM	DPM	Inform	Reserve and schedule the resources to transport the item back to the supported unit.		
31.0	DPM	DE	Inform	DPM generates and sends the relevant work order to DE so as to carry out the return.		
DE delivers the repaired item back to the supported unit.						
32.0	DE	Supported Unit	Inform	Fulfills delivery of repaired item		
33.1	DE	DPM	Inform	Signal item delivery.		
33.2	DPM	DCM	Inform	Signal item delivery.		
33.3	DCM	OM	Inform	Signal item delivery.		
34.0	OM	Supported Unit	Inform	Verify receipt and condition of the item from Supported unit.		
35.0	OM	FM	Inform	Send invoice – optional.		

Figure 5.1.8 Maintenance at IMA

5.1.9 Maintenance at Customer

Using unit identifies a need for a maintenance service that must be fulfilled by the logistics chain (Garrison or deployed). Maintenance Capacity Management (MCM) has capability to perform this service. Service performed at customer site. This scenario applies to both parts on hand and/or for parts not on hand.

Step	Speaker	Listener	Performative	Content Description	Attributes/ Media	Comments
1.1	Supported Unit	Supervisor	Ask	The supported unit identifies the requirement and sends it to the supervisor for validation.	Unit Identification, NSNs Quantity, Location - **Text, Digital, Voice**	The request could be sent as an e-form. The location information is identified by the GPS enabled device and sent along with the form. The voice acts as a backup for human – human.
1.2	Supervisor	RM	Inform	The supervisor validates the identified requirement and submits it to RM	Secure signature - **Encryption**	Usually password encrypted
2.0	RM	OM	Inform	If unable to source internally then RM submits the request to OM on behalf of the supported unit.	Request Identification + 1.1 - **Text, Digital**	In addition to the request form a request ID is automatically generated by the system which would be some digital information
2.1	OM	RM	Inform			
3.1	OM	MCM	Ask	Ask the availability of resources (man power, tools and parts).		
3.2	MCM	OM	Accept	Depending on the availability of the resources MCM accepts or rejects the request.		
4.1	OM	DCM	Ask	Ask the availability of the Transportation for the pick up of products and the relevant tools to bring it to the supported unit.		
4.2	DCM	OM	Accept	Depending on the availability of the resources DCM either accepts or rejects the request.		
5.1	OM	MCM	Ask / Accept	Assess the capability of ICM to accepting the products.		

5.2	MCM	OM	Accept			
6.1	OM	DCM	Ask / Accept	Assess the capability of DCM for making the distribution resources available.		
6.2	DCM	OM	Accept			
7.0	OM	Supported Unit	Inform	Confirm with the using unit by reiterating the requirement and the terms and conditions for pick up and return.	Request ID confirmation - **Text (short message) Voice**	Confirmation of the request can be achieved by sending the request ID back and forth with the customer.
8.1	OM	FM	Ask / Accept	Optional – In case funds are to be credited for the return then OM asks FM about availability of the funds.	- **Text, encryption, digital**.	The total cost repair is presented as an e-form. It is encrypted and sent for confirmation of availability of funds.
8.2	FM	OM	Accept			
9.0	OM	MCM	Inform	Inform MCM to reserve and schedule the maintenance.		
10.0	OM	DCM	Inform	Informs in advance the need for distribution capacity for the maintenance.		
11.0	MCM	MPM	Inform	Inform MPM to reserve and schedule.	Order ID, NSNs - **Text, Voice**	The specific list of resources is sent so as to enable the IPM to reserve the resources.
12.0	MCM	DCM	Inform	Inform the relevant shipping requirements.		
13.0	MCM/ DCM	DCM/MCM	Inform / Accept	Co-ordination for pick up		
14.0	MCM	OM	Inform	Signal the delivery requirements		
15.1	MPM	ME	Inform	Assigns the resources from the execution element for this particular task.	Work order ID, Item ID - **Text, Voice**	Generated work order is sent to the ME so as perform the required tasks.
15.2	ME	MPM	Inform			
16.0	DCM	DPM	Reserve	The specific resources are reserved.	Transporting unit ID, Time to pick-up, Location - **Text, Voice, Digital**	The identified products are listed out and sent.
17.1	DPM	DE	Inform	Place a work order for the pick-up from using unit and delivery to the MCM of the products to be repaired.	Item ID, Location, Destination location - **Text, Voice**	The location from where to pick-up the item and product lists are sent using

						the e-forms.
17.2	DE	DPM	Inform			
18.0	OM	Supported Unit	Inform			
19.0	DE	Supported Unit	Inform			
20.1	DE	DPM	Inform			
20.2	DPM	DCM	Inform			
20.3	DCM	OM	Inform			
ME now conducts diagnosis and inspection, and MPM identifies and requests the additional resources and parts to effect repair if necessary.						
21.1	ME	MPM	Inform	Send the signal about the additional resource requirements.		
21.2	MPM	MCM	Inform	Send the signal about the additional resource requirements.		
22.0	MCM	OM	Inform	Notify new ATP/CTP (optional)		
23.0	OM	Supported Unit	Inform	(Optional)		
24.0	OM	FM	Inform	(Optional)		
25.0	MCM	xCM	Inform	Signals for additional resources and parts and reserves additional capacity/capability to effect repair. (Optional)		
ME performs repair and conducts quality control.						
26.1	ME	MPM	Inform	Notify repair completion.	**- Text (short message)**	
26.2	MPM	MCM	Inform	Signals repair completion.	**- Text (short message)**	
26.3	MCM	OM	Inform	Notify repair completion.	**- Text (short message)**	
27.0	ME	Supported Unit	Inform	(Notify) Release/delivers repaired item to using unit (physical flow)		
28.0	OM	Supported Unit	Ask	Verifies receipt and satisfactory condition with using unit.		
29.0	MPM	DCM	Inform	Arrange for return of contact teams as required.		
30.0	OM	FM	Inform	Signals receipt verification	**- Text, Encryption**	
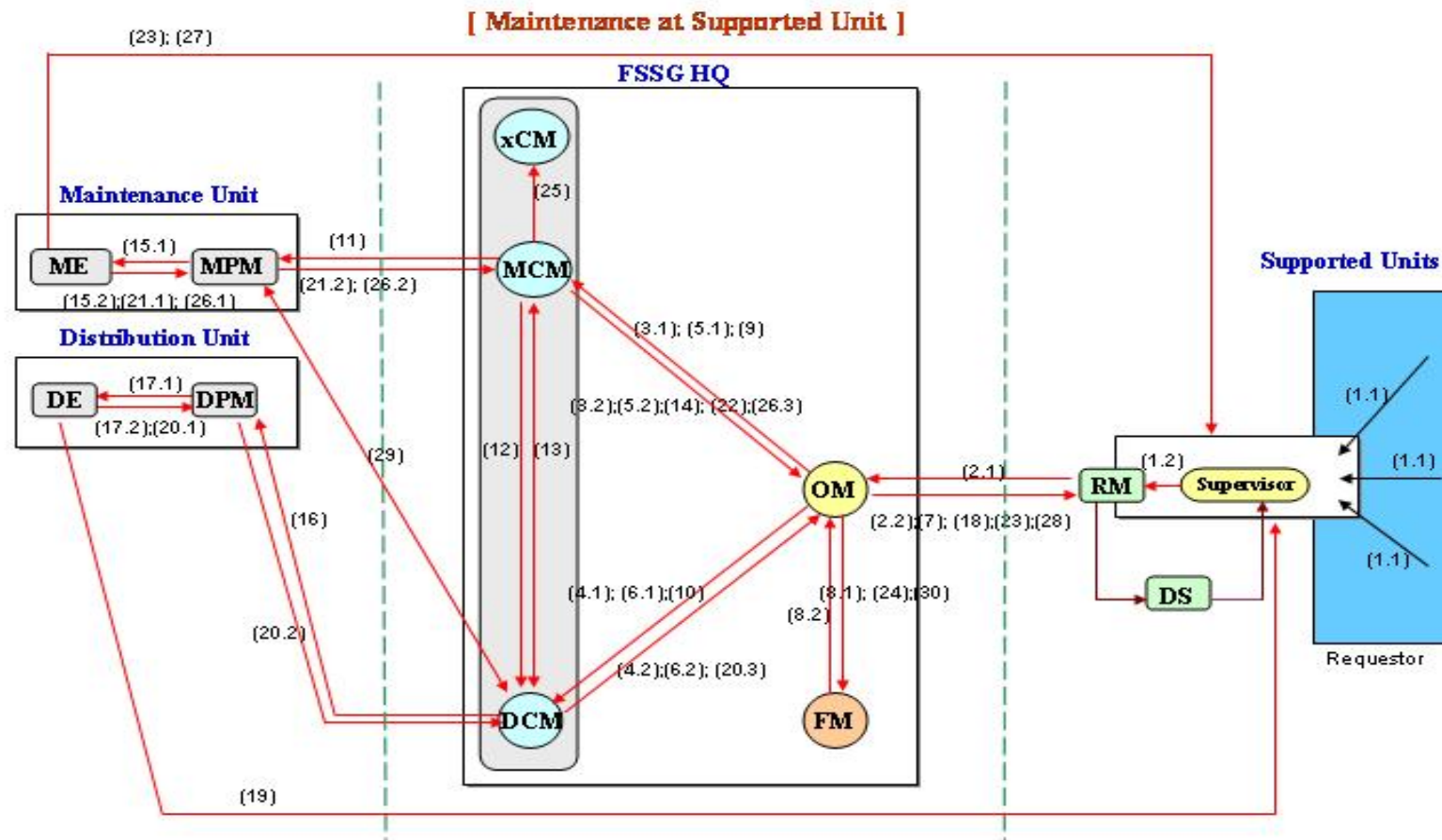
Figure 5.1.9 Maintenance at Supported Unit

5.1.10 PROCUREMENT FULFILLMENT

Appropriate capacity management (xCM) identifies or receives a need for a product/service that must be fulfilled by the

logistics chain (Garrison or Deployed) that must be sourced externally.

Step	Speaker	Listener	Performative	Content Description	Attributes/ Media	Descriptions
1.0	xCM	PCM	Request	Submit the order	Unit Identification, NSNs Quantity, Location, Expected time for replenishment. - **Text, Digital, Voice**	The order could be sent as an e-form. The location information is identified by the GPS enabled device and sent along with the form. The voice acts as a backup for human – human.
2.0	PCM	PPM	Ask	Reserve and Schedule	NSNs, Quantity, Order ID, Time frame. - **Text, Voice**	The list and quantity of items and time frame can be sent using text forms.
3.0	PPM	PE	Inform	Route the order for the fulfillments	2.0 + Location info, route - **Text voice Digital**	The location information is obtained from the GPS and is sent as a digital code.
4.0	PE	Provider/ Supplier	Ask	Check availability and capability	Confirmation - **Text, Voice**	
5.0	PE	Provider/ Supplier	Ask	Negotiates to deliver products/services within the customer's requirement.	Negotiation - **Voice**	
6.1	PE	Provider/ Supplier	Request	Release the order		
6.2	PE	PPM	Inform	Inform the order releasing.		
6.3	PPM	PCM	Inform	Inform the order releasing.		
7.1	PCM	PPM	Inform	Notify or receipt verification and provider payment. Finally to PE.		
7.2	PPM	PE	Inform	Inform 7.1. (PE is actual listener)		
8.0	PE	PPM	Inform	Inform that sourcing order is closed.		

Figure 5.1.10 Procurement Fulfillment

DISTRIBUTION

5.1.11   Basic Distribution for Product Order Fulfillment

Distribution of ordered product from point to another.

Step	Speaker	Listener	Performative	Content Description	Attributes/ Media	Comments
1.0	ICM	DCM	Ask	ICM depending on the need for distribution makes a work order and transfers it to DCM	Unit Identification, NSNs Quantity, origin location, destination location, Time constraints - **Text, Digital, Voice, Encryption**	The request can be sent as e-forms while the location information is automatically generated from the GPS system and sent along with the request.
2.0	DCM	DPM	Inform	DPM identifies the relevant mode for distribution and checks availability. Further reserves the resources for the particular work order.	Request Identification, Unit Identification, NSNs Quantity, origin location, destination location, Time constraints - **Text, Voice**	Identification of the required resources and their availability can be tracked using auto identification. The flags for reserving the relevant resources can be sent using e-form and voice.
3.0	DPM	ICM	Inform	DPM generates the load plan based on the requirements and informs the same to ICM	Requirements description, Time for execution. - **Text, Voice**	
4.1	DPM	ICM	Inform	Signal evaluation results (capability, availability, cost, schedule, etc.).	Confirmation about the reserved resources and the relevant terms for the service are sent to ICM. - **Text, Voice**	The results from evaluation can be sent across to the ICM or can also be published in a web-based interface.
4.2	DPM	OM	Inform	Signal evaluation results (capability, availability, cost, schedule, etc.).	Confirmation about the reserved resources and the relevant terms for the service are sent to OM. - **Text, Voice**	The results from evaluation can be sent across to the ICM or can also be published in a web-based interface.
5.0	DPM/	ICM/	Ask / Accept	Coordinate to finalize load sequence plan.	Co-ordination	

	ICM	DPM			- **Text, Voice**	
6.0	DPM	DE	Ask/ Accept	Generate work order and inform the execution unit about the schedule.	Work order; MHE (material handling equipment) ID, Location information, Time frame. - **Text, Voice, encryption**	Location information has to be encrypted and the work order can be sent as an e-form. Since execution personnel are involved voice communication is also necessary.
7.1	DE	DPM	Inform	Notify item delivery.	Confirmation of item delivery - **Text (short message), Voice**	The confirmation can be sent using a short message and a voice back-up.
7.2	DPM	DCM	Inform	Notify item delivery.	Confirmation of item delivery - **Text (short message), Voice**	
7.3	DCM	OM	Inform	Notify item delivery.	Confirmation of item delivery - **Text (short message), Voice**	
8.0	OM	Supported Unit	Inform	Verify receipt.	Receipt of item delivered is sent and OM verifies the same. - **Text, Voice, Encryption**	
9.0	OM	FM	Inform	Signal receipt verification.	Invoice is sent to FM and is recorded as a completed transaction. **Text, Encryption**	
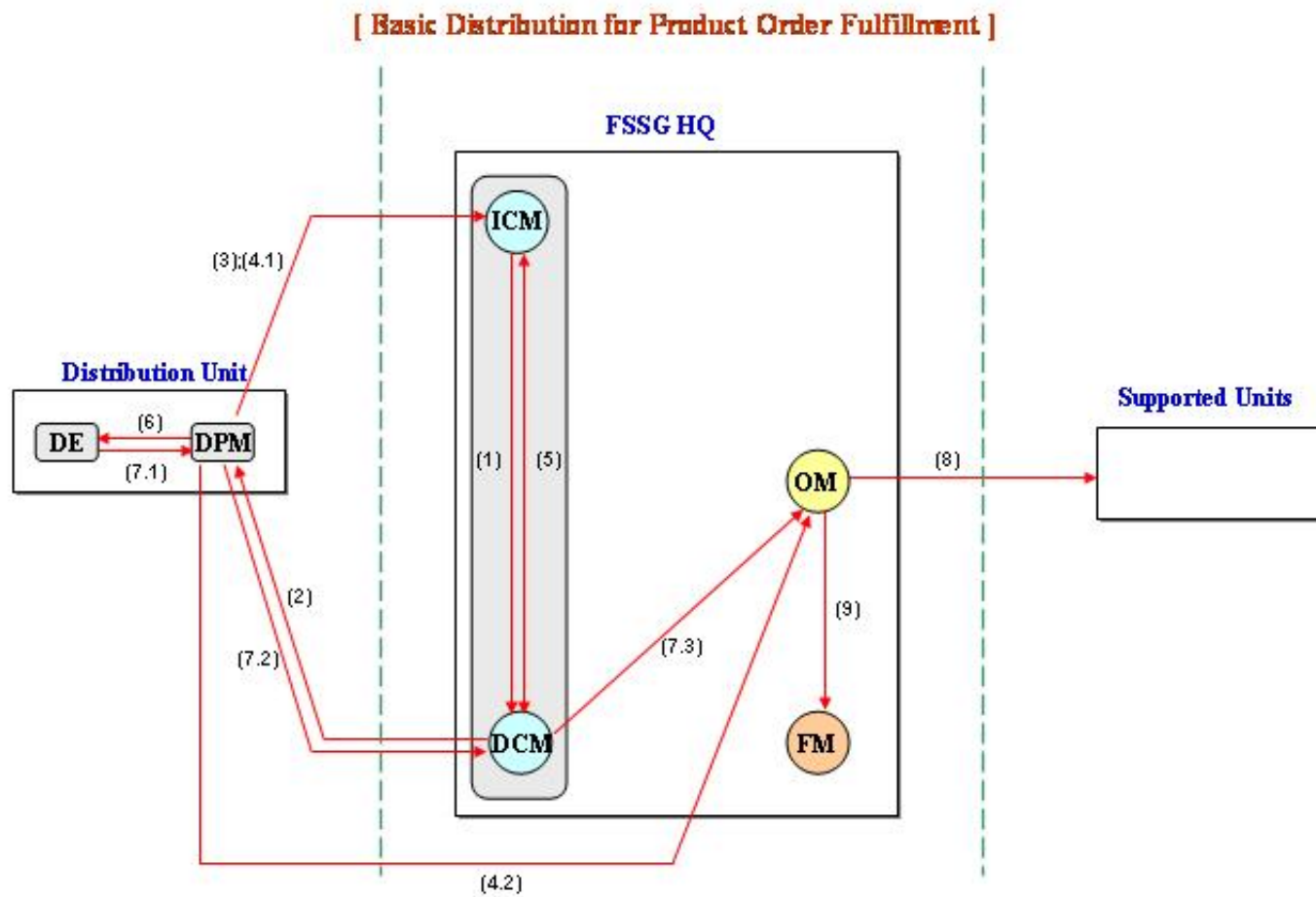
Figure 5.1.11 Basic Distribution for Product Order Fulfillment

DISTRIBUTION

5.1.12   Movement of Personal and Equipment for Services One-Way

Basic movement of unit PAX (Passengers) and equipment from one location to another.

Step	Speaker	Listener	Performative	Content Description	Attributes/ Media	Descriptions
1.1	Supported unit	Supervisor	Ask	Submit request for the movement of passengers or equipment from one place to another.	Unit Identification, origin, destination, type of transportation, time frame - **Text, Digital, Voice**	The request could be sent as an e-form. The location information is identified by the GPS enabled device and sent along with the form. The voice acts as a backup for human – human.
1.2	Supervisor	RM	Inform	Submit the request with appropriate authentication to RM after validating it.	Secure signature - **Encryption**	Usually password encrypted
2.0	RM	OM	Inform	Submit and inform about the requirements on behalf of the supported unit.	- **Text, Digital**	In addition to the request form a request ID is automatically generated by the system which would be some digital information
3.0	OM	DCM	Ask/ Accept	Check and confirm availability of distribution.		
4.0	OM	DCM	Ask	Assess capability to complete service within the terms and conditions (time frame) of the request.		
5.0	OM	Supported unit	Inform	Confirm the request with the supported unit and reconcile terms and conditions for service.	- **Text** (short message)	
6.0	OM	FM	Inform	Inform the need to commit or transfer funds if required for many internal functions this may be optional.	- **Text Voice Encryption**	
7.0	OM	DCM	Inform	Identify appropriate resources and direct DCM to reserve and generate schedule.	Unit ID, Order ID, origin, destination, transportation type, time frame	

						- **Text, Digital, Voice**	
8.0	DCM	DPM	Inform	DCM in turn conveys the need to reserve and schedule specific resources under its control.	Unit ID, Order ID, origin, destination, transportation type, time frame - **Text, Digital, Voice**	
9.1	DPM	DCM	Inform	Make the necessary load plan and notify built load plan for PAX and equipment.	- **Text Voice**	
9.2	DCM	OM	Inform	Forward the built load plan for PAX and equipment.		
10.1	DPM	DCM	Inform	Signal evaluation results of carrier capability, availability, cost, carrier schedules, etc.	- **Text, Voice**	
10.2	DCM	OM	Inform	Signal evaluation results of carrier capability, availability, cost, carrier schedules, etc.		
11.1	DPM	DCM	Inform	Notify generated load sequence plan.	- **Text (short message)**	
11.2	DCM	OM	Inform	Notify generated load sequence plan.		
12.0	DPM	DE	Inform	Generate the work order and assign to relevant execution unit.	Unit ID order ID, origin, destination, time frame, and type of transportation.	
13.1	DE	DPM	Inform	Notify delivery/completion of tasks.	- **Text, Voice**	
13.2	DPM	DCM	Inform	Forward notification of item delivery/completion of task.	- **Text, Voice**	
13.3	DCM	OM	Inform	Forward notification of item delivery/completion of task.		
14.0	OM	Supported unit	Inform	Verify receipt of the transferred equipment or the completion of the tasks from supported unit.	- **Text, Voice**	
15.0	OM	FM	Inform	Signal receipt verification.	- **Text, Voice, encryption**	
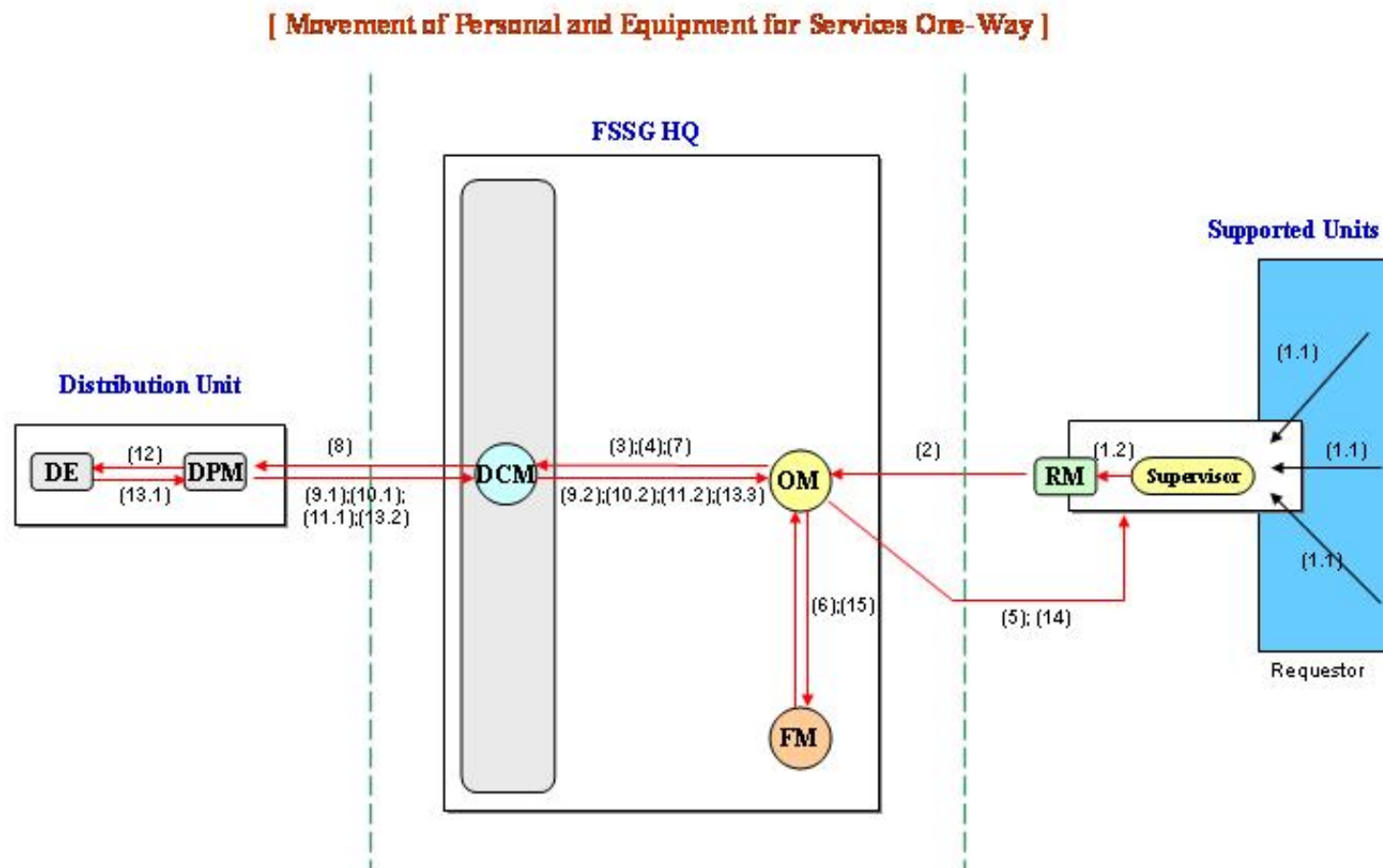
Figure 5.1.14 Movement of Personal and Equipment for Services One-Way

HEALTH SERVICES

5.1.13   Patient Movement

Supported unit identifies a need for patient movement that must be fulfilled by the logistics chain (Garrison or Deployment). Health Services Support (HSS) has the capacity to perform the appropriate level of patient care required. Service performed at the next level of care with all materials available.

Step	Speaker	Listener	Performative	Content Description	Attributes/ Media	Descriptions
1.1	Supported Unit	Supervisor	Ask	Inform the requirement for the patient movement. Route it through supervisor.	Unit Identification, location, type of transportation - **Text, Digital, Voice**	The request could be sent as an e-form. The location information is identified by the GPS enabled device and sent along with the form. The voice acts as a backup for human – human and will be used dominantly depending on the urgency.
1.2	Supervisor	RM	Inform	After accepting the requirement.	Secure signature - **Encryption**	Usually password encrypted
2.0	RM	OM	Inform	Submit and inform about the requirements on behalf of the supported unit.	Request Identification + 1.1 - **Text, Digital**	In addition to the request form a request ID is automatically generated by the system which would be some digital information
3.1	OM	HSCM	Ask / Accept	Check and confirm the availability of health resources to provide services.		
3.2	HSCM	OM	Accept			
4.1	OM	DCM	Ask / Accept	Check and confirm the availability of the distribution to support movement requirements.		
4.2	DCM	OM	Accept			
5.1	OM	HSCM	Ask / Accept	Assess the capability to provide health service.		
5.2	HSCM	OM	Accept			

| 6.1	OM	DCM	Ask / Accept	Assess the capability to provide distribution services within the terms and conditions.		
6.2	DCM	OM	Accept			
7.0	OM	Supported Unit	Inform	Reconcile customer terms and conditions and obtain confirmation.		
8.1	OM	FM	Inform			
8.2	FM	OM	Inform			
9.0	OM	HSCM	Inform	Reserve and schedule resources.		
10.0	OM	DCM	Inform	Send advance notice about the distribution requirements..		
11.0	HSCM	HSPM	Inform	Direct the HSPM to identify the relevant resources and reserve them.		
12.0	HSCM	DCM	Inform	Notify shipping requirements.		
13.1	DCM/ HSCM	HSCM/ DCM	Ask / Accept	Coordinate pickup to meet delivery requirements.		
13.2	HSCM	OM	Inform	Signal delivery requirements.		
14.1	HSPM	HSE	Inform	Generate the service order and assign resources towards completing the service order.		
14.2	HSE	HSPM	Inform			
14.3	HSPM	HSCM	Inform			
15.0	DCM	DPM	Inform	Direct the DPM to reserve and schedule resources.		
16.1	DPM	DE	Inform	Route order to appropriate DE for fulfillment.		
16.2	DE	DPM	Inform			
DE moves patient requiring treatment to next level of care.						
17.1	DE	DPM	Inform	Signal patient movement.		
17.2	DPM	DCM	Inform	Signal patient movement.		
17.3	DCM	OM	Inform	Signal patient movement.		
18.0	OM	HSCM	Inform	Verify receipt.		
19.0	OM	FM	Inform	Signal Receipt verification.		
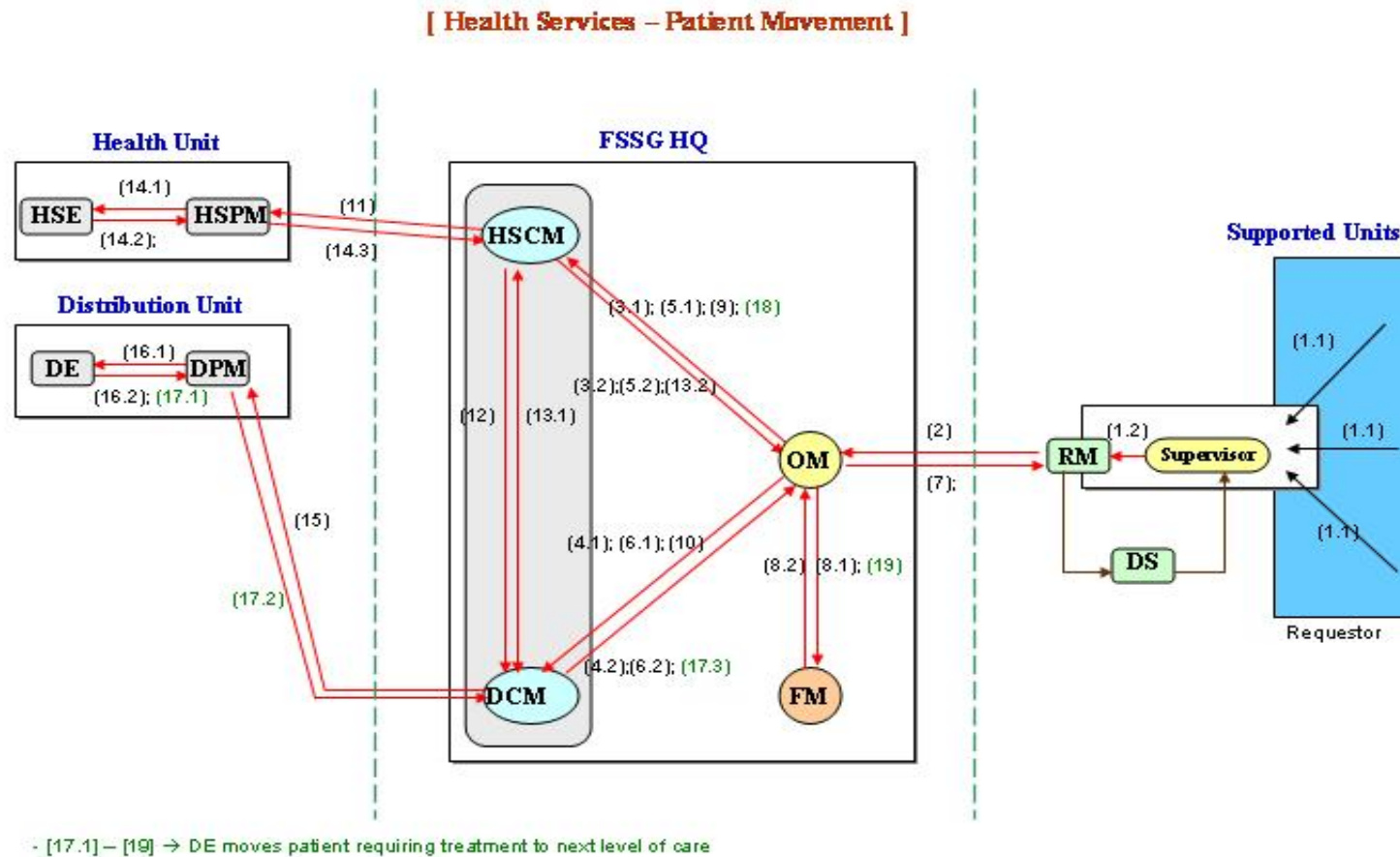
Figure 5.1.13 Health Services – Patient Movement

5.1.14 Health Service at Customer (Supported Unit) Site

Supported unit identifies a need for health services support that must be fulfilled by the logistics chain (Garrison or Deployment). Health Services Support (HSS) has the capacity to perform the appropriate level of health service required. Service performed at the customer (supported unit) site.

Step	Speaker	Listener	Performative	Content Description	Attributes/ Media	Descriptions
1.1	Supported Unit	Supervisor	Ask	Inform the requirement for the patient movement. Ask supervisor for validation.	Unit Identification, Location, requirements - **Text, Digital, Voice**	The request could be sent as an e-form. The location information is identified by the GPS enabled device and sent along with the form. The voice acts as a backup for human – human.
1.2	Supervisor	RM	Inform	After accepting the requirement.	Secure signature - **Encryption**	Usually password encrypted
2.0	RM	OM	Inform	Submit and inform about the requirements on behalf of the supported unit.	Request Identification - **Text, Digital**	In addition to the request form a request ID is automatically generated by the system which would be some digital information
3.1	OM	HSCM	Ask / Accept	Check and confirm the availability of health resources to provide services.		
3.2	HSCM	OM	Accept			
4.1	OM	DCM	Ask / Accept	Check and confirm the availability of the distribution to support movement requirements.		
4.2	DCM	OM	Accept			
5.1	OM	HSCM	Ask / Accept	Assess the capability to provide health service.		
5.2	HSCM	OM	Accept			
6.1	OM	DCM	Ask / Accept	Assess the capability to provide distribution services within the terms and conditions.		
6.2	DCM	OM	Accept			
7.0	OM	Supported	Inform	Reconcile customer terms and conditions	Confirmation of the request	Reiterating the request ID

		Unit		and obtain confirmation.	**-Text (Short message)**	and also confirming to requirements can do request confirmation.
8.1	OM	FM	Inform	Inform the need for funds if needed.	**- Text, encryption**	
8.2	FM	OM	Inform			
9.0	OM	HSCM	Inform	Reserve and schedule.		
10.0	OM	DCM	Inform	Sends advance notice.		
11.0	HSCM	HSPM	Inform	Reserve and schedule appropriate resources.		
12.0	HSCM	DCM	Inform	Notify shipping requirements.		
13.1	DCM/ HSCM	HSCM/ DCM	Ask / Accept	Coordinate pickup to meet delivery requirements.		
13.2	HSCM	OM	Inform	Signal delivery requirements.		
14.1	HSPM	HSE	Inform	Assign resources to the service order.	Order ID, resource list, location, time frame. **-Text, Voice**	
14.2	HSE	HSPM	Inform			
15.0	DCM	DPM	Inform	Reserve and schedule resources for transporting the service to the supported unit..	Work order id, type of transportation origin destination, time frame **- Text, Voice,**	
16.1	DPM	DE	Inform	Route order to appropriate DE for fulfillment.	Work order id, type of transportation origin destination, time frame **- Text, Voice,**	
16.2	DE	DPM	Inform			
DE delivers HSE (Contact team/ resources) to work site (supported unit).						
17.1	DE	DPM	Inform	Inform completion of the delivery to team on site.	Confirmation of the completion of task. **- Text (short message)**	
17.2	DPM	DCM	Inform	Forward signal about completion of the delivery to team on site.	Confirmation of the completion of task. **- Text (short message)**	

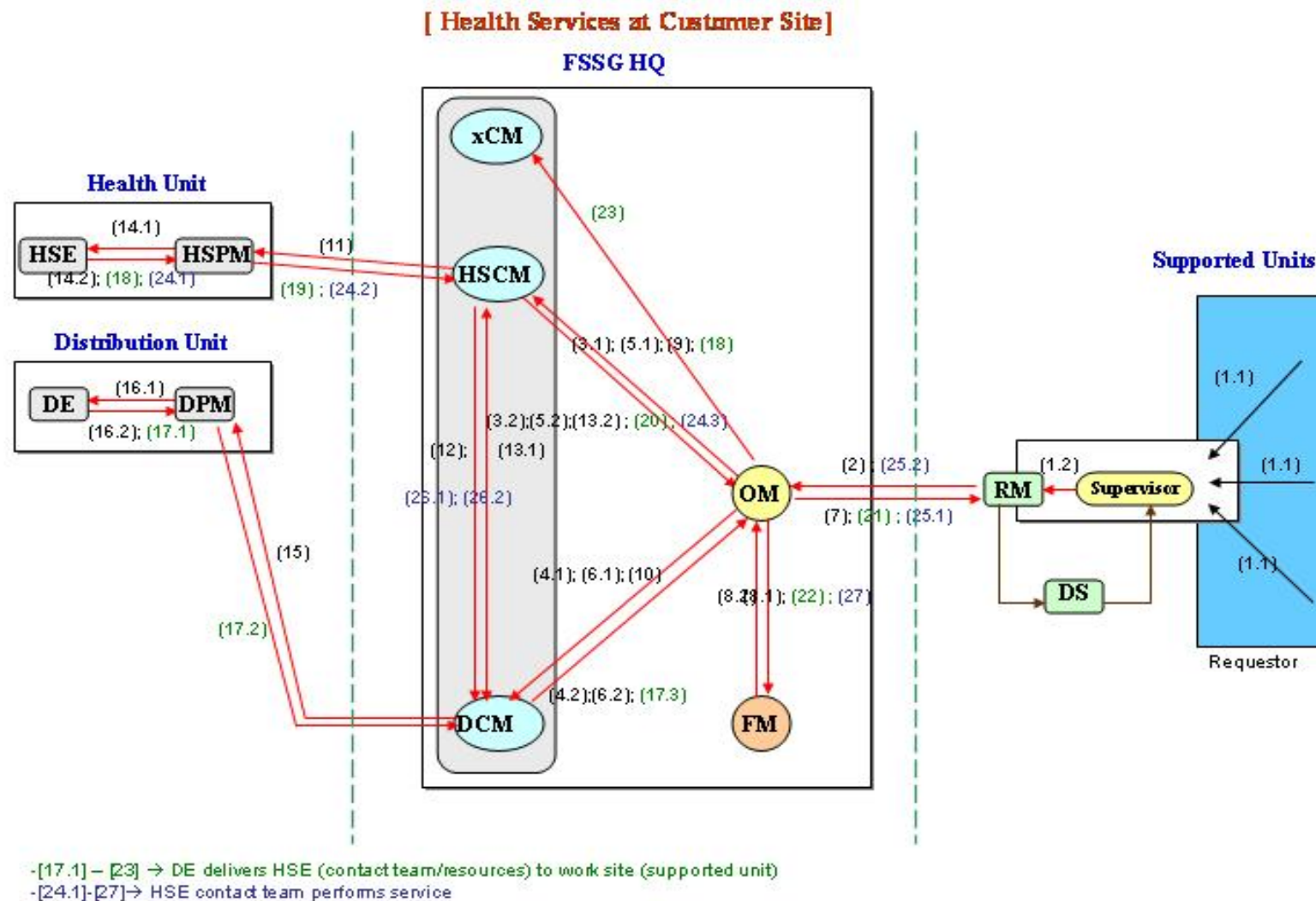| 17.3	DCM	OM	Inform	Forward signal about completion of the delivery to team on site.	Confirmation of the completion of task. **- Text (short message**	
18.0	HSE	HSPM	Inform	Inform team conduct assessment.		
19.0	HSPM	HSCM	Inform	Identify and request additional resources and supplies to effect health service.	**- Text, Voice, request ID**	
20.0	HSCM	OM	Inform	Notify new ATP/CTP.		
21.0	OM	Supported Unit	Inform	Reconcile ATP/CTP.	**- Text (short message)**	
22.0	OM	FM	Inform			
23.0	OM	XCM	Inform	Signal for additional resources and supplies and reserves additional capacity/capability to effect health service.		
HSE contact team performs service.						
24.1	HSE	HSPM	Inform	Notify the service completion.		
24.2	HSPM	HSCM	Inform	Forward signal about the service completion.		
24.3	HSCM	OM	Inform	Forward signal about the service completion.		
25.1	OM	Supported Unit	Ask/ Accept	Verify satisfactory performance.		
25.2	Supported Unit	OM	Accept			
26.1	HSCM	DCM	Ask/ Accept	Arrange for return of contact team as required.		
26.2	DCM	HSCM	Accept			
27.0	OM	FM	Inform	Signal Receipt verification.	**- Text, Encryption**	

Figure 5.1.14 Health Services at Customer Site

ENGINEERING SERVICE

5.1.15   Engineering Services Using Organic Resources

For engineering services that can be performed using organic resources (skills, man hours) with support equipment and supplies on-hand.

Step	Speaker	Listener	Performative	Content Description	Attributes/ Media	Descriptions
1.1	Supported unit	Supervisor	Ask	Identify the requirements and transfer the information to the supervisor for validation	Unit Identification, requirements, Location, expected time for fulfillment - **Text, Digital, Voice**	The request could be sent as an e-form. The location information is identified by the GPS enabled device and sent along with the form. The voice acts as a backup for human – human.
1.2	Supervisor	RM	Inform	After accepting the request.	Secure signature - **Encryption**	Usually password encrypted
2.0	RM	OM	Inform	Submit and inform about the requirements on behalf of the supported unit.	Request Identification - **Text, Digital**	In addition to the request form a request ID is automatically generated by the system which would be some digital information
3.1	OM	ESCM	Ask / Accept	Check and confirm availability of resources.		
3.2	ESCM	OM	Accept			
4.1	OM	DCM	Ask / Accept	Ask the availability of the distribution to support movement requirement.		
4.2	DCM	OM	Accept			
5.1	OM	ESCM	Ask / Accept	Assess the capability to complete engineering service.		
5.2	ESCM	OM	Accept			
6.1	OM	DCM	Ask / Accept	Assess the capability to provide distribution within the terms and conditions.		
6.2	DCM	OM	Accept			
7.0	OM	Supported	Inform	Confirm the request with the supported unit	Reiterate requirements	

		Unit		and reiterate the terms and conditions for service.	and terms and conditions **- Text (short message), Voice**	
8.1	OM	FM	Inform	If need be then the FM has to be informed about the need for committing or transferring funds.	**- Text, encryption**	
8.2	FM	OM	Inform			
9.0	OM	ESCM	Inform	Reserve and schedule engineering service.		
10.0	OM	DCM	Inform	Sends advance notice.		
11.0	ESCM	ESPM	Inform	Reserve and schedule.	Resource id, description of requirements, work order **- Text, voice**	
12.0	ESCM	DCM	Inform	Notify shipping requirements.		
13.1	DCM/ ESCM	ESCM/ DCM	Ask / Accept	Coordinate pickup to meet delivery requirements.		
13.2	ESCM	OM	Inform	Signal delivery requirements.		
14.1	ESPM	ESE	Inform	Assign resources to the service order.	Work order, Time frame, unit ID location **- Text, voice**	
14.2	ESE	ESPM	Inform			
15.0	DCM	DPM	Inform	Reserve and schedule.	Location information, type of resources, work order **- Text, voice**	
16.1	DPM	DE	Inform	Route order to appropriate DE for fulfillment.	Location information, type of resources**,** work order **- Text, voice**	
16.2	DE	DPM	Inform			
17.0	DE	Supported Unit	Inform	Notify delivery of ESE (Contact team/resources) to Supported Unit.	**- Text (short message)**	
18.1	DE	DPM	Inform	Signal delivery.		
18.2	DPM	DCM	Inform	Signal delivery		
18.3	DCM	OM	Inform	Signal delivery		
19.1	ESE	ESPM	Inform	Signal the detailed engineer estimation once it is done.		

| 19.2	ESPM	ESCM	Inform	Signal the detailed engineer estimation once it is done.		
19.3	ESCM	OM	Inform	Notify estimation status.		
** Request for Additional Resources						
20.0	ESPM	ESCM	Inform	Signal identification and request of additional resources and parts to effect engineering service.		
21.0	ESCM	OM	Inform	Notify new ATP/CTP		
22.0	OM	Supported Unit	Inform	Reconcile ATP/CTP		
23.0	OM	FM	Inform	If need be then the FM has to be informed about the need for committing or transferring funds.	**- Text, encryption**	
24.0	ESCM	xCM	Inform	Signal to appropriate xCM for additional resource and parts and reserve additional capacity/capability to effect engineering service.		
25.1	ESCM	ESPM	Inform	Notify required resources.		
25.2	ESPM	ESE	Inform	Notify required resources.		
**ESE executes engineering service and conducts quality control.						
26.1	ESE	ESPM	Inform	Signal completion of engineering service.		
26.2	ESPM	ESCM	Inform	Signal completion of engineering service.		
26.3	ESCM	OM	Inform	Signal completion of engineering service.		
27.0	OM	Supported Unit	Ask/ Accept	Verify receipt and satisfactory performance.		
28.0	ESCM	DCM	Ask/ Accept	Arrange return of contact team and retrograde of resources no longer needed.		
29.0	OM	FM	Inform	Receipt verification.		
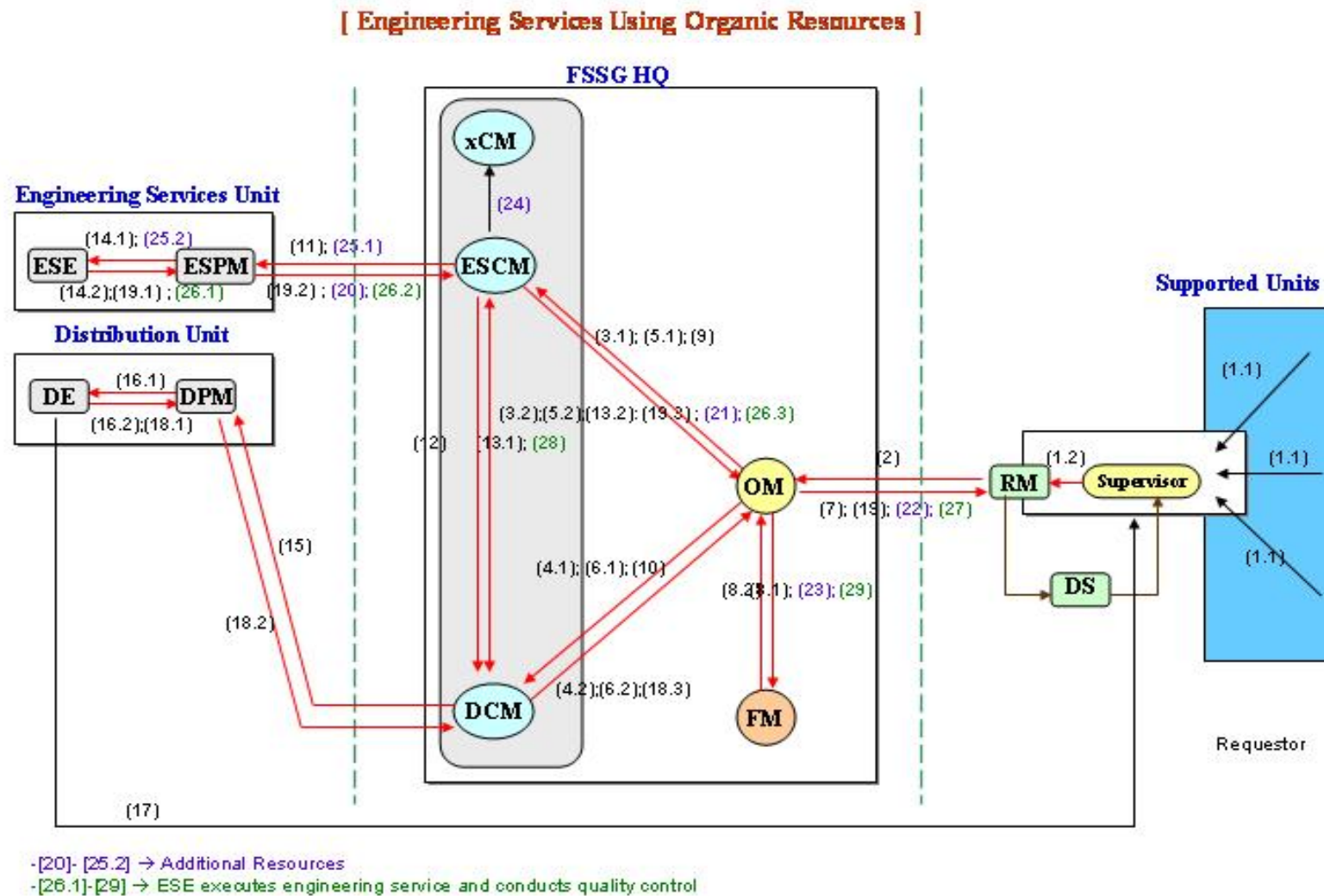
Figure 5.1.15 Engineering Services Using Organic Resources

CUSTOMER SERVICE

5.1.16   Problem Related To a Customer Order

Supported unit identifies a problem regarding fulfillment of a product/service for an open order. The problem cannot be resolved solely by the OM, i.e. it requires further problem analysis before a COA can be identified.

Step	Speaker	Listener	Performative	Content Description	Attributes/ Media	Descriptions
1.1	Supported Unit	Supervisor	Ask	The supported unit identifies the problem or requirement and passes it on to the supervisor for validation.	Unit ID, Problem description, requirements. - **Text, Digital, Voice**	The request could be sent as an e-form. The location information is identified by the GPS enabled device and sent along with the form. Since this involves problem description the voice communication will play and important role..
1.2	Supervisor	OM	Inform	Analyzes the problem and submits it to OM with appropriate authentication.	Secure signature - **Encryption**	Usually password encrypted
2.0	OM	CSE	Inform	OM signals the CSE and initiates creation of the customer service order.	Problem description - **Text, Digital**	In addition to the request form a request ID is automatically generated by the system which would be some digital information
3.0	CSE/OM	OM/CSE	Ask / Accept	Both OM and CSE coordinate to identify the issue.	- **Text, Voice**	
4.0	CSE	OM	Inform	Transfers the identified course of action (COA) back to OM	- **Text, Voice**	
5.0	OM	Supported Unit	Inform	Confirm and decide COA.	- **Text, Voice**	
6.0	OM	Supported Unit	Inform	Reconcile order terms and conditions with ATP/CTP.		
7.0	OM	FM	Inform			
8.0	OM	CSE	Inform	OM approves the identified COA		
9.0	CSE	OM	Inform	Once the issue is resolved CSE signals to		

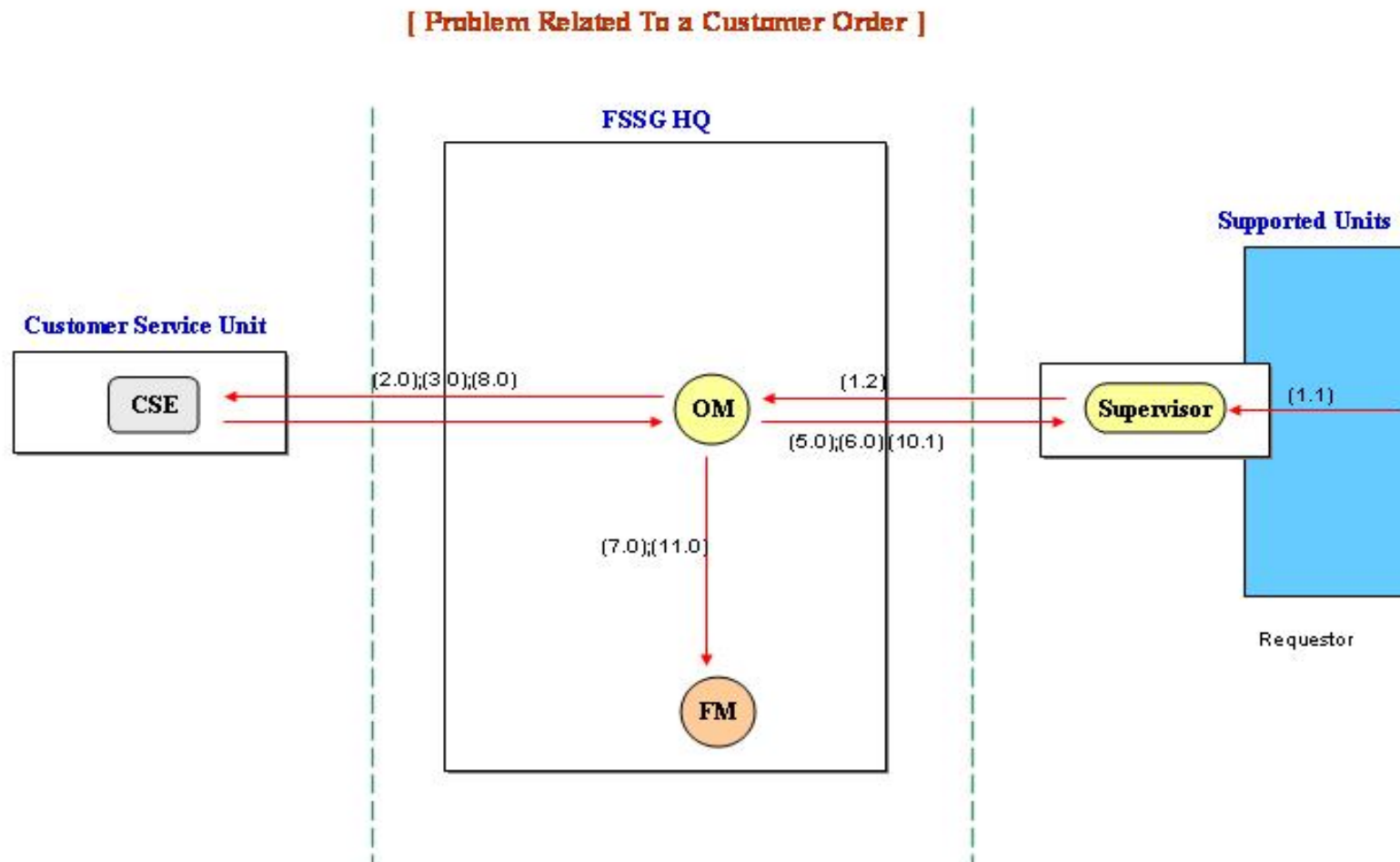|						
				OM about completion of task.		
10.1	OM	Supported Unit	Inform	Confirms with the supported unit if the issue has been resolved and if it is satisfactory.		
10.2	OM	CSE	Inform	Verify resolution.		
11.0	OM	FM	Inform	Optional – Send invoice in case financial transactions are needed.	**-Text, Voice, Encryption**	

Figure 5.1.16 Problem related to a Customer Order

5.1.17   Customer Service-Customer Inquiry

Supported unit has an inquiry (not related to a specific order) and notifies CSE directly.

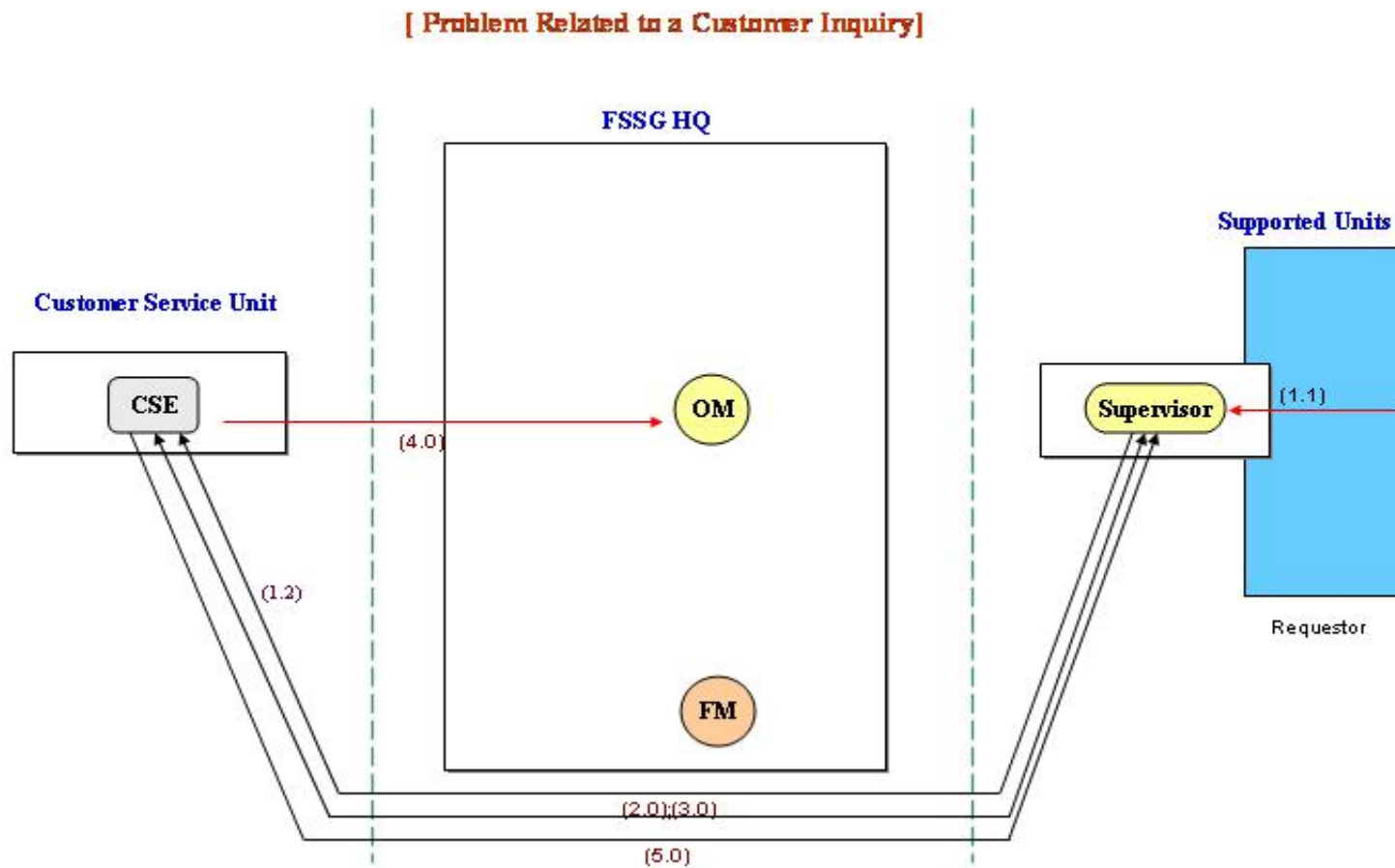| Step	Speaker	Listener	Performative	Content Description	Attributes/ Media	Descriptions
1.1	Supported Unit	Supervisor	Ask	Identify the particular enquiry and send it to supervisor.	Unit Identification, NSNs Quantity, Location - **Text, Digital, Voice**	The request could be sent as an e-form. The location information is identified by the GPS enabled device and sent along with the form. The voice acts as a backup for human – human.
1.2	Supervisor	CSE	Ask	Submit the inquiry/service order	Secure signature - **Encryption**	Usually password encrypted
2.0	CSE/ Supported Unit	Supported Unit /CSE	Ask / Accept	Coordinate further to identify the issue.	- **Text, Voice**	In addition to the request form a request ID is automatically generated by the system which would be some digital information
3.0	CSE	Supported Unit	Ask / Accept	Confirm COA, and set expectations around resolution date/time.		
4.0	CSE	OM	Inform	Notify that inquiry has been successfully answered.		
5.0	CSS	Supported Unit	Inform	Verify resolution.		

Figure 5.1.17 Problem related to a Customer Inquiry